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Double-contrast arthrography and internal derangement
of the

TEMPOROMANDIBULAR JOINT

by

Per-Lennart Westesson



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Title and subtitle Double-contrast arthrography and internal derangement of the TEMPOROMANDIBULAR JOINT			
Abstract Double-contrast arthrotomography was applied to temporomandibular joints and demonstrated clearly the position and configuration of the disc, its attachments and the articular surfaces. In a correlative study on autopsy specimens the diagnostic accuracy of this technique was close to 80%. In patients, the disc was normally biconcave and lying with its posterior band superior to the condyle. Anterior displacement of the disc was the most frequent observation when double-contrast arthrotomography was applied to patients with clinical signs of internal derangement. In addition to displacement the disc could also be perforated and/or deformed taking on a biconvex shape. In patients with clicking the anteriorly displaced disc was repositioned in association with clicking during opening. In patients with a history of clicking substituted by limitation of opening the disc was constantly displaced anterior to the condyle, blocking anterior condylar translation. The patients with limitation of opening had more pain, more signs of mandibular dysfunction, more hard tissue changes and more frequent perforation and deformation of the disc compared to patients with clicking only. The mechanism of clicking was studied in temporomandibular joint autopsy specimens by the aid of arthrography combined with cineradiography and high-speed cinematography. Clicking was observed in joints with anteriorly displaced disc. In association with clicking the condyle rapidly slid under the posterior band of the disc. Clicking occurred at the instant when the condyle, with the disc or posterior attachment in between, impacted on the temporal articular surface. In an autopsy material, temporomandibular joints with altered position and configuration of the disc exhibited osteoarthritis. Joints with biconcave disc in superior position exhibited normal articular surfaces. Double-contrast arthrotomography seems to facilitate the diagnosis of internal derangement by an improved radiographic image of the intra-articular anatomy. The diagnostic accuracy of this technique should in clinical work be more than 80%. Patients with clinical signs of internal derangement may have anterior disc displacement with or without repositioning of the disc on opening. Internal derangement may in some cases be a precursor of osteoarthritis.			
Key words Temporomandibular joint; arthrography, autopsy specimen, cineradiography, clicking, cryosectioning, double-contrast arthrography, dysfunction, function, high speed cinematography, internal derangement, osteoarthritis, pathology, radiology, tomography.			
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PREFACE

This thesis is based on the following papers, which will be referred to by their Roman numerals:

- I. Westesson P-L, Omnell K-A & Rohlin M. Double-contrast tomography of the temporomandibular joint. A new technique based on autopsy specimen examinations. Acta Radiol (Diagn) (Stockh) 1980, 21, 777-784
- II. Westesson P-L & Rohlin M. Diagnostic accuracy of double-contrast arthrotomography of the temporomandibular joint. Correlation between arthrography and morphology on autopsy specimens using dissection and cryosectioning. Submitted for publication
- III. Isberg-Holm A & Westesson P-L. Movement of disc and condyle in temporomandibular joints with clicking. An arthrographic and cineradiographic study on autopsy specimens. Acta Odontol Scand 1982, 40, 153-166
- IV. Isberg-Holm A & Westesson P-L. Movement of disc and condyle in temporomandibular joints with and without clicking. A high-speed cinematographic and dissection study on autopsy specimens. Acta Odontol Scand 1982, 40, 167-179
- V. Westesson P-L. Double-contrast arthrotomography of the temporomandibular joint. Introduction of an arthrographic technique for visualization of the disc and articular surfaces. Submitted for publication
- VI. Eriksson L & Westesson P-L. Clinical and radiological study of patients with anterior disc displacement. Swed Dent J, accepted for publication

VII. Westesson P-L & Rohlin M. Internal derangement related to osteoarthrosis in temporomandibular joint autopsy specimens. In manuscript

GLOSSARY

Arthrography:

- Single-contrast arthrography: Radiography of a joint after injection of, in general, an radiopaque contrast material. Synonyms: Mono contrast arthrography, opaque arthrography, positive contrast arthrography. Arthrography using air as contrast medium is termed pneumo-arthrography.
- Single-contrast arthrotomography: Single-contrast arthrography with tomography.
- Double-contrast arthrography: A small amount of opaque contrast material coats the articular surfaces and the joint compartments are expanded by injected air.
- Double-contrast arthrotomography: Double-contrast arthrography with tomography. Synonym used in papers I, III, IV: Double-contrast tomography.

Cannula:

- A tube for example of teflon, for insertion into joint compartment. During insertion (=cannulation) the lumen of the cannula is occupied by a trocar.

Clicking:

- A distinct cracking, snapping sound, which should be distinguished from crepitation - multiple grinding, scraping sounds.
- In reciprocal clicking, clicking during mandibular retrusion will not occur unless it is preceded by clicking during mandibular opening (described by Ireland 1951, termed by Farrar 1978). Reciprocal clicking is a clinical sign of anterior disc displacement with reduction.

Disc configuration:

- In a sagittal section the disc is normally biconcave. The anterior and posterior thick parts are termed anterior and posterior bands (Rees 1954; Blaschke et al. 1980). Synonym used in papers III, IV: Anterior and posterior ridges. The bilaminar region (Rees 1954) posterior to the posterior band is termed posterior attachment. Synonyms: Retrodiscal pad (Blackwood 1969). Posterior disc articular attachment (Wilkes 1978 a,b).

Disc position:

- Normally the posterior band of the disc is situated superior to the condyle i.e. superior superior position (Fig 1 A, paper VI).
- Displacement: For displacement of the disc the terminology recommended by the Sixth Annual Temporomandibular Joint Research Seminar (Chicago, July, 1979, Katzberg et al. 1980 b) has been used.
- Anterior disc displacement with reduction: Disc at intercuspal position located anterior to its normal superior position. On opening the disc will be repositioned (reduced) to normal superior position usually in association with clicking (Fig 1 B, paper VI). Synonym: Anterior subluxation (Dolwick et al. 1979) anterior displacement 1° - 3° (Bronstein et al. 1981).
- Anterior disc displacement without reduction: Disc at intercuspal position located anterior to its normal superior position. On opening the disc will not be repositioned (reduced) to normal superior position (Fig 1 C, paper VI). Synonyms: Closed lock (Wilkes 1978 a,b), anterior dislocation (Dolwick et al. 1979),

anterior displacement 4° (Bronstein et al. 1981).

- Oblique disc position: Anterior position laterally or laterally as well as centrally combined with superior position medially.

Internal derangement:

- Internal derangement of a joint (Hey 1814) implies a localized mechanical fault which interferes with the smooth action of a joint. Internal derangement is by definition distinct from osteoarthritis and implies interposition of soft tissue (Adams 1982). The principal internal derangement of the temporomandibular joint is anterior displacement of the articular disc (Wilkes 1978 a).

Osteoarthritis:

- Non inflammatory disorder of the movable joint characterized by deterioration and abrasion of the articular cartilage, and also by formation of new bone at the articular surface (Sokoloff 1969). In the following osteoarthritis has been defined as changes associated with breakdown of the articular surface layer, resulting in, e.g. fibrillation and fissuring of the articular surfaces and perforation of the disc (Carlsson & Öberg 1979). Synonyms: Arthritis, degenerative joint disease, osteoarthritis.

Remodelling:

- Remodelling in human joints was by Johnson (1962) classified into: progressive, regressive and circumferential and was defined by Moffet et al. (1964) as the changes associated with a proliferative response in the articular tissue. Remodelling has also been

considered as rebuilding of the subarticular soft and hard tissue layers mainly related to proliferative processes (Carlsson & Öberg 1979).

Tomography:

- Radiographic technique by which structures in one predetermined section of tissue, are selectively visualized with both location and thickness adjustable. Structures on both sides of the tomographic plane are blurred to that extent that they are obscured. Synonym: Body section radiography.
- In simultaneous tomography, comprehensively described by Backlund (1956), several films, depicting different tissue layers, are exposed simultaneously. Synonym: Multisection tomography.
- Lateral tomography of the temporomandibular joint implies latero-medial projection corrected for the angulation of the condyle in the horizontal plane.
- Frontal tomography of the temporomandibular joint implies antero-posterior or postero-anterior projection perpendicular to the lateral tomography.

INTRODUCTION

Symptoms of mandibular dysfunction are common (Hansson & Nilner 1975; Helkimo 1979; Solberg et al. 1979; Egermark-Eriksson et al. 1981; Nilner 1981; Nilner & Lassing 1981). The symptoms are often related to the temporomandibular joint and for this reason, radiographic examination of the joint is often included in the diagnostic procedure. Conventional radiography depicts the hard tissue components of the joint. However, abnormalities are often located in the soft tissues (Steinhardt & Langen 1933; Blackwood 1963, 1969; Moffett et al. 1964; Carlsson et al. 1968, Öberg et al. 1971; Lindvall et al. 1976; Bean et al. 1977; Hansson & Öberg 1977; Wilkes 1978 a,b; Farrar & McCarty Jr 1979 b; Katzberg et al. 1980 a,b). These abnormalities are not readily demonstrated with conventional radiography. This limitation of conventional radiography has led to the development of arthrography which demonstrates the soft tissue components of the joint.

The importance of correct diagnosis instead of a syndromal approach, was emphasized by Moffett (1980). He also claimed that the difficulties patients may have in obtaining successful treatment of temporomandibular joint afflictions originate in diagnostic inadequacies. Correct diagnosis was also pointed out by Carlsson et al. (1981) as the most important prerequisite for determining whether or not to operate on temporomandibular joints.

Historic perspective of arthrography

Werndorff & Robinson (1905) used oxygen as contrast medium and were the first to apply arthrography to a knee only ten years after Roentgen's discovery of x rays. Positive contrast arthrography was performed on cadavers in the early 1900s, but the available contrast

media were too toxic for use on patients. When safe urographic positive contrast media had been developed they were also used for arthrography.

Zimmer (1941) was the first to report on arthrography of the temporomandibular joint. His experience was limited and somewhat discouraging. Nørgaard (1944, 1947), however, must be given the credit of the development of a standard technique and for demonstrating its value as a diagnostic tool. After his pioneer work many years elapsed before others reported the use of temporomandibular joint arthrography (Campbell 1965; Frenkel 1965; Takaku 1967; Mattila 1968; Agerberg & Lundberg 1971; Kraszewski et al. 1972; Chao-chü et al. 1973; Toller 1974). The limited application of Nørgaard's technique was probably not only due to the difficult injection technique but also to difficulties with interpretation of the arthrogram. The lack of successful therapeutic methods directly based on arthrographic diagnosis may also have decreased the interest in temporomandibular joint arthrography.

Current status of temporomandibular joint arthrography

From the late 1970s there has been an increasing positive interest for the use of temporomandibular joint arthrography, as reflected by a number of publications (Lynch & Chase 1978; Wilkes 1978 a,b; Dolwick et al. 1979; Farrar & McCarty Jr 1979 b; Katzberg et al. 1979; Blaschke 1980; Blaschke et al. 1980; Helms et al. 1980; Katzberg et al. 1980 a,b; Rasmussen 1980; Barrs et al. 1981; Blaschke 1981; Bronstein et al. 1981; Katzberg et al. 1981; Murphy 1981; Murphy & Adams 1981; Ntailianas & Spengos 1981). Three factors may have led to this renewed interest. The first was the use of an image intensifier as a tool for facilitating correct cannulation of the temporomandibular joint (Wilkes 1978 a,b). The second factor was the arthrographic identifi-

cation of anterior disc displacement, also considered as the principle internal derangement of this joint (Wilkes 1978 a) and elucidation of its role in the temporomandibular joint pain dysfunction syndrome (Wilkes 1978 a,b). The third factor, probably the most important one, was the introduction of new concepts for conservative (Farrar 1978) and surgical therapy (McCarty Jr & Farrar 1979) for correction of anterior disc displacement based on accurate information on the disc. Elimination of overlapping structures by the use of tomography simplifies the interpretation of the arthrograms. Although arthrography with tomography had already been used by Nørgaard (1947) in a few examinations of cadavers and by Campbell (1965) and Frenkel (1965) in clinical examinations, this simplified interpretation may also have influenced the renewed positive interest in temporomandibular joint arthrography.

Selection of single-contrast versus double-contrast examinations

For the temporomandibular joint single-contrast arthrography has been the almost exclusively used method. Double-contrast arthrography for the knee and other joints was introduced by Bircher (1931) and described by Bircher and Oberholzer (1934) and Oberholzer (1938). Double-contrast arthrography has been used for the ankle (Olsson 1981), the elbow (del Buono 1961; del Buono & Solarino 1962; Eto et al. 1975; Pavlov et al. 1979; Horns 1981; Hudson 1981) and the shoulder (Ghelman & Goldman 1977; Goldman & Ghelman 1978; Dalinka 1980 b; Arndt 1981; Resnick 1981). The double-contrast technique for the knee has been widely applied (for reviews see Freiburger & Kaye 1979; Thijn 1979; Dalinka 1980 a; Arndt et al. 1981), whereas only few attempts have been made to use this technique for the temporomandibular joint (Arnaudow et al. 1968; Arnaudow & Pflaum 1974).

Resnick (1981) emphasized that double-contrast examinations are more difficult to perform and interpret, are more time consuming and require more examiner skill than their single-contrast counterparts. On the other hand the information yielded by double-contrast arthrography of the knee and shoulder has been considered superior to that resulting from single-contrast arthrography (Butt & McIntyre 1969; Horns 1977; Goldman & Ghelman 1978).

The potential of double-contrast arthrotomography of the temporomandibular joint can be explored by application to autopsy specimens. Subsequent dissection and visual inspection of the joints provides anatomical feedback facilitating interpretation of the arthrogram.

Diagnostic accuracy of temporomandibular joint arthrography

In spite of difficulties to inspect, survey and document the temporomandibular joint during surgery, attempts have been made to correlate arthrographic and surgical findings. In such studies on patients the diagnostic accuracy of single-contrast arthrography of the temporomandibular joint has been estimated to be between 81% and 97% (Nørgaard 1947; Agerberg & Lundberg 1971; Bronstein et al. 1981).

However, a systematic correlation between arthrography and morphology cannot be successfully conducted on patient material, as only selected temporomandibular joint disorders are treated surgically. Furthermore, arthrograms which display pathologic condition is usually one of the prerequisites for surgical intervention. Therefore, the detection of false-negative findings is unlikely. A correlative study employing a double-contrast technique does not seem to be reported in the literature.

Temporomandibular joint clicking

Clicking is one of the widely accepted signs of temporomandibular joint dysfunction and a frequent observation in both epidemiological studies (Helkimo 1974; Hansson & Nilner 1975; Molin et al. 1976; Lysell 1977; Solberg et al. 1979; Pöllman 1980) and in clinical studies (Carraro et al. 1969; Molin 1973; Rosell & Öberg 1975; Choy & Smith 1980; Rasmussen 1981; Hansson et al. 1982).

The etiology and mechanism of clicking have raised much speculation and different events leading to clicking have been discussed (for reviews see Yavelow & Arnold 1971; Rasmussen 1973). Thus, deviation in form of articulating surfaces (Steinhardt 1934, 1957), local thickenings of the articulating tissue layers (Nanthaviroj et al. 1976) as well as condyle and/or disc displacement have been proposed as factors giving rise to clicking (Pringle 1918-1919; von Staphelmohr 1929; Axhausen 1931; Rees 1954; Steinhardt 1957, Shore 1959; Freese 1962; Nanthaviroj et al. 1976).

Arthrography on patients with clicking demonstrated that clicking occurred during or after the sliding of the condyle under the posterior band of the disc (Wilkes 1978 a; Dolwick et al. 1979; Farrar & McCarty Jr 1979 a,b). These investigations have been limited to observations and registration of stationary joints prior to and after clicking. In order to delineate the course of events in association with clicking a combination of arthrography and cineradiography would be preferable.

Studies on temporomandibular joint clicking have mostly been concerned with the movement of the joint components (for review see paper III). Temporomandibular joint sounds have been studied in several papers (Ekensten

1952; Quellette 1974; Watt 1963, 1966, 1980, 1981) but a satisfactory explanation of the origin of the sound has not been given. Steinhardt (1957) proposed that clicking occurred at the end of the opening movement when the condyle hit the temporal component after having slipped over the anterior band of the disc. Campbell (1963) discussed the sound in the context of the hypothesis that it is a result of the creation of a vacuum. However, he found it difficult to fit this hypothesis to temporomandibular joints. According to Yavelow & Arnold (1971) elimination of abnormal pressure of synovial fluid resulted in clicking.

Direct observation of clicking joints during movement using high speed cinematography with simultaneous sound recording might reveal what actually causes the sound.

Anterior disc displacement in patients

Since it was surgically identified by Annandale in 1887, disc displacement has been extensively discussed in the literature (Pringle 1918-1919; Wakely 1929; Burman & Sinberg 1946; Ireland 1951; Kiehn 1952; Silver, Simon & Savastano 1956; Ward 1961; Silver & Simon 1963; Campbell 1965; Middleton 1970; Farrar 1971; Toller 1974; Farrar 1978). However, it was not until the late 1970s that Wilkes (1978 a,b) elucidated the role of anterior disc displacement in temporomandibular joint pain and dysfunction by combining clinical, arthrographical and surgical observations. He concluded that the mechanism responsible for the symptoms concerned the competency of the posterior articular disc attachment. His observations were confirmed by Farrar & McCarty Jr (1979 b), Katzberg et al. (1980 a,b) and Bronstein et al. (1981).

Clicking or a history of clicking followed by limitation of opening have been suggested as clinical signs

of anterior disc displacement (Wilkes 1978 a,b; Farrar & McCarty Jr 1979 b; Katzberg et al. 1980 b). Clinical examination of the stomathognathic system followed by double-contrast arthrotomography ought to provide additional information on the association between clinical and radiological features of patients with anterior disc displacement.

Internal derangement related to osteoarthritis

In a general survey of orthopaedic disorders internal derangement of joints was proposed as one main predisposing factor for the development of osteoarthritis (Adams 1981). Speculations have been raised that anterior disc displacement, considered as the principal internal derangement of the temporomandibular joint (Wilkes 1978 a), may progress to osteoarthritis (Wilkes 1978 a,b; Farrar & McCarty Jr 1979 b; Blaschke et al. 1980; Katzberg et al. 1980 b; Bronstein et al. 1981).

The sequela of progression may be studied post mortem and several autopsy investigations have documented distribution and prevalence of osteoarthritis of the temporomandibular joint (Blackwood 1963; Öberg et al. 1971; Lindvall et al. 1976; Bean et al. 1977). However, recent concepts of position and configuration of the disc (Wilkes 1978 a,b; Farrar & McCarty Jr 1979 b; Katzberg et al. 1980 a,b) have not been related to osteoarthritis.

AIMS OF THE INVESTIGATION

1. To develop a technique for double-contrast arthrotomography of the temporomandibular joint and to apply it to autopsy specimens in order to explore its potential (I).
2. To investigate the diagnostic accuracy of double-contrast arthrotomography of the temporomandibular joint, and to describe diagnostic errors made (II).
3. To delineate the mechanism of temporomandibular joint clicking in autopsy specimens (III).
4. To investigate what actually caused the sound and to study structural changes in temporomandibular joint autopsy specimens with clicking (IV).
5. To apply double-contrast arthrotomography to patients and to describe the radiographic intra-articular anatomy of normal joints and of joints with internal derangement (V).
6. To compare clinical and arthrographic findings in patients displaying anterior disc displacement with and without reduction (VI).
7. To study the association between internal derangement and osteoarthritis in temporomandibular joint autopsy specimens (VII).
8. To define indications for arthrography of the temporomandibular joint.

MATERIAL

Autopsy specimens I-IV, VII

Temporomandibular joint autopsy specimens were removed via the middle cranial fossae from cadavers without infectious diseases. The block measured approximately 10 cm x 8 cm x 6 cm.

Patients V, VI

Patients revealing clinical signs of internal derangement, such as clicking, locking, limitation of opening and pain were referred to our department for double-contrast arthrotomography of the temporomandibular joint. There were 79 females and 26 males with a mean age of 33 years (range 12-75).

METHODS

I. A technique for double-contrast arthrotomography of the temporomandibular joint was developed and applied to autopsy specimens. The technique included injections and radiography during which the specimens were mounted in a positioning device. Injections into the joint compartments were made in the sequence: air, water-soluble iodine contrast medium and air.

A Philips Universal Polytome with hypocycloidal movement and a multi-film cassette containing five films with 3 mm interspaces and matching sets of intensifying screens were used. Two directions of tomographic sectioning were employed; lateral and frontal. Ten tomograms were obtained in each direction and were distributed approximately throughout the latero-medial and antero-posterior dimension of the joint. Following radiography the specimens were dissected.

II. The diagnostic accuracy of double-contrast arthrotomography was investigated on 52 temporomandibular joint autopsy specimens by correlating arthrographic findings with morphologic observations.

Lateral double-contrast arthrotomography was performed and the radiographic appearance of configurations and position of the disc for each joint was interpreted simultaneously by the authors. Dissection or cryosectioning followed and the radiographic appearance of the disc was compared to the morphology. Agreements and disparities were systematized and attempts were made to explain the disparities.

III. In order to delineate the condylar path cineradiography was performed on five temporomandibular joint autopsy specimens which demonstrated clicking when the condyle was moved in an antero-posterior direction. The movement of the disc was studied with arthrography combined with cineradiography. The relation between clicking and movement of condyle and disc was investigated with simultaneous sound recording. Structural changes were studied by conventional radiography, tomography and double-contrast arthrotomography.

IV. In order to disclose what actually caused the sound in temporomandibular joint autopsy specimens with clicking, the joint compartments were opened laterally to make direct observations of the joint compartments possible. In spite of this opening clicking still occurred. A high speed cinematographic technique (250 and 500 frames/s, c.f.:normal 24 frames/s) with simultaneous sound recording was applied to the five clicking joints and to four joints without clicking. The multi-colour film was studied in slow motion and the movements associated with clicking were analysed frame by frame with reference to time. Dissection followed high-speed

cinematography and the disc and articular surfaces were examined macroscopically.

V. In clinical work the technique of double-contrast arthrotomography was gradually modified during 123 examinations of 105 patients with signs of internal derangement. After local anesthesia the joint compartments were cannulated and iodine contrast medium (Amipaque®) was injected under fluoroscopic observation first into the lower and then into the upper compartment. Jaw movements were studied fluoroscopically. The excessive of iodine contrast medium was aspirated and about half a milliliter of air was injected into each compartment. Lateral tomography was performed at intercuspal position and at maximum opening as well as prior to and after clicking.

VI. Fifty-five patients displaying temporomandibular joint clicking or a history of clicking followed by limitation of opening were subjected to a detailed clinical examination followed by radiographic examination including double-contrast arthrotomography. Findings in the patients with clicking were compared to those in the patients with a history of clicking followed by limitation of opening.

VII. One hundred and twenty-seven right temporomandibular joint autopsy specimens were dissected. The position and configuration of the discs were related to osteoarthritis of the articular surfaces.

RESULTS

I. It was possible to obtain double-contrast arthrotomogram of excellent quality of the temporomandibular joint autopsy specimens. Generally, the disc was visualized with a very good definition, particularly in lateral arthrotomography.

The appearance of the joint compartments and the disc depended upon the level of sectioning and the position of the condyle as well as upon the amount of air injected. In some joints, the configuration of the disc was biconcave in some sections, and of even thickness in others. The best over-all view was obtained from the central part of the joint both in the lateral and the antero-posterior views with the condyle positioned inferiorly in the fossa. It was often difficult to obtain a definite outline of the disc by frontal tomography. However, the configuration and attachments of the disc to the lateral and medial poles of the condyle were generally clearly depicted. Inspection of the dissected joints facilitated interpretation of the double-contrast arthrotomograms.

II. The arthrotomographic diagnosis was confirmed at dissection or cryosectioning in 41 of 52 joints signifying a diagnostic accuracy in this sample of 79%.

In 11 joints there were disparities between arthrotomographic and morphologic findings of configuration and position of the disc. The configuration was misinterpreted in three joints, the position in seven joints and configuration and position in one joint. The errors were grouped into observation errors (two joints), insufficient examination (four joints) and limitation of tomographic reproduction of the lateral part (five joints). There were six false-positive reports due to

observation errors of insufficient examination, whereas limitation of tomographic reproduction resulted in six false-negative reports.

Eleven disc perforations were diagnosed by opacity of the upper compartment after injection of contrast media into the lower compartment. All perforations were verified at dissection or cryosectioning. Eight perforations were extensive and definitely demonstrated on double-contrast arthrotomograms.

III. Clicking was associated with an increased condylar velocity and an inferiorly directed bulge in the condylar path. Superimposition of the graphs of the protrusive and retrusive condylar paths assigned to joints with reciprocal clicking revealed that the posterior part of the retrusive condylar path ran inferior to the protrusive condylar path.

In joints with reciprocal clicking the disc was pushed anterior to the condyle during protrusion. Inferior to the articular tubercle a retardation of condylar movement was seen followed by a rapid movement inferiorly-anteriorly-superiorly. Simultaneously, the disc rapidly moved posteriorly. These events were associated with clicking. As a result the condyle passed the posterior band of the disc and was located inferiorly to the central thin part of the disc where it remained during the rest of the protrusion.

During retrusion the condyle remained inferior to the central thin part of the disc until the last stage of condylar movement in the fossa. A simultaneous rapid movement of the disc and condyle associated with clicking then took place. The condyle mainly moved superiorly while the disc moved anteriorly-inferiorly. As a result of these movements the disc was displaced

to a position anterior to the condyle. This was the initial position for protrusion and a prerequisite for protrusive clicking to occur.

In the one joint with non-reciprocal clicking, the condyle and disc moved synchronously in association with clicking.

IV. Joints without clicking demonstrated a synchronized movement of the disc and condyle during protrusion and retrusion. In the fossa, the condyle was placed inferior to the posterior band of the disc. At the end of protrusion the condyle was located inferior to the transition between the central thin part and the anterior band of the disc.

In joints with reciprocal clicking, movements of disc and condyle during protrusion and retrusion were in agreement with the results of the previous arthrographic and cineradiographic studies of the same joints (III). A scrutiny of the rapid movements associated with clicking both during protrusion and retrusion revealed that the condyle rapidly passed under the posterior band of the disc immediately prior to clicking. Clicking was recorded at the instant the condyle, with the disc or posterior attachment in between, hit the temporal articular surface. The time for the passage of the condyle under the posterior band of the disc was calculated to be 0.008-0.038 s.

In one joint with a non-reciprocal clicking the condyle was invariably placed inferior to the central thin part of the disc during protrusion and retrusion and no smooth condylar rotation against the inferior surface of the disc took place. In association with clicking, the movement of the condyle and disc was still synchronized. Clicking occurred in association with a jump by

the condyle and disc but these could not be seen to actually impact on the temporal joint component.

Radiographically structural hard tissue changes were found in all but one of the joints with clicking. At dissection all joints exhibited remodellings but none osteoarthritis.

V. When applied to patients, and after gradual modification, double-contrast arthrotomography depicted clearly the configuration and position of the disc, its attachment to the capsule anteriorly and posteriorly and the configuration of the joint compartments. The best outline of the disc and articular surfaces was obtained from the central part of the joint. Immediately after injection, the iodine contrast medium was confined to the walls of the joint compartments, but gradually penetrated the soft tissues. After 15 minutes good arthrotomograms could no longer be obtained.

Twenty-seven examinations (22%) revealed radiographically normal temporomandibular joints, characterized by the disc being biconcave and at intercuspal position located with the posterior band superior to the condyle.

Forty-one temporomandibular joints (33%) exhibited anterior disc displacement with reduction. This was characterized by the posterior band at intercuspal position lying anterior to the condyle and by elongation of the posterior disc attachment. During mouth opening, clicking or hesitation was observed. This was associated with changed disc position from anterior displacement to normal superior position (i.e. reduction). During the following closing sequence another, usually more discrete, clicking or hesitation was registered and the disc was again anteriorly displaced. Twenty-nine of 41 temporomandibular joints with anterior

disc displacement with reduction exhibited an oblique disc position. The disc configuration in the 41 temporomandibular joints displaying anterior disc displacement with reduction varied from normal biconcave to biconcave with marked thickening and enlargement of the posterior band and simultaneous antero-posterior shortening of the central thin part and anterior band.

Forty-eight examinations (39%) revealed temporomandibular joints with anterior disc displacement without reduction. This was characterized by the posterior band of the disc lying anterior to the condyle both at intercuspal position and at maximum opening. The posterior disc attachment was elongated. The dense part of the disc had a changed configuration, varying from slight thickening and enlargement of the posterior band of a biconcave disc to a biconvex disc. In eleven joints with anterior disc displacement without reduction perforation was fluoroscopically diagnosed by simultaneous opacification of the upper compartment during injection of contrast medium into the lower compartment.

The remaining seven examinations (6%) showed granulomatous arthritis (two joints), osteoarthritis (three joints) and adhesions (two joints).

Following arthrographic examination, the patients experienced transient discomfort usually as tenderness during one or two days (range 0-8 days). There were no serious complications.

VI. Patients with temporomandibular joint clicking or with a history of clicking followed by limitation of opening were at arthrographic examination found to have anterior disc displacement. Patients with clicking showed displacement with reduction and the disc was repositioned in association with clicking during opening.

Patients with a history of clicking followed by limitation of opening showed displacement without reduction. The disc was locked anteriorly in displaced position to the condyle, blocking the anterior condylar translation. Compared to patients with clicking the patients with limitation of opening, had more pain, more signs of mandibular dysfunction, more hard tissue changes and higher frequency of perforation and deformation of the disc.

VII. On the average individuals with osteoarthritis were slightly older than those with normal articular surfaces. Superior disc position was usually associated with biconcave configuration whereas anterior position was associated with biconvex configuration. In joints with oblique disc position the configurations of the disc was often different in the lateral, central and medial thirds of the joint. Osteoarthritis affected 39% of the joints and was most frequently found in the lateral third of the tubercle. Biconvex discs in anterior position were associated with osteoarthritis whereas biconcave discs in superior position were associated with normal articular surfaces.

DISCUSSION

Arthrography

A procedure for clinical double-contrast arthrotomography of the temporomandibular joint evolved after gradual modifications of the technique developed in and applied to autopsy specimens. With knowledge of anatomy, experience and use of fluoroscopic guidance the joint compartments could be successfully cannulated in nearly all examinations as found by Blaschke et al. (1980). After an initial period of difficulties arthrography was easily applied with little discomfort for the patient. The resulting double-contrast arthrotomograms clearly demonstrated position and configuration of the disc.

It was beyond the scope of these papers to systematically compare the information yielded by single- and double-contrast arthrography of the temporomandibular joint. Judging from my clinical experience and published single-contrast arthrotomograms (Wilkes 1978 a,b; Dolwick et al. 1979; Blaschke 1980; Blaschke et al. 1980; Katzberg et al. 1980 a,b; Blaschke 1981), the double-contrast technique seem to offer an improved radiographic representation of the intra-articular anatomy. However, the diagnostic outcome of single- and double-contrast arthrography ought to be compared in an experimental study on animals or autopsy specimens.

Temporomandibular joint arthrography has been performed by injection of contrast medium into the lower compartment (Farrar & McCarty Jr 1979 a,b; Murphy & Adams 1981, Murphy 1981) or the upper compartment (Rasmussen & Besserman 1977; Rasmussen 1980). These one-compartment arthrograms may show perforation of the disc as well as the configuration of the joint compartment injected. According to Farrar & McCarty Jr (1979 a,b) the position

of the disc can be indirectly determined from the appearance of the anterior recess of the lower compartment. However, the configuration of the disc can not be disclosed by arthrography with injection of contrast medium only into one compartment. Delineation of disc configuration is essential for complete diagnosis (VII) and requires contrast medium in both the upper and lower compartments. Additionally, by this technique the position of the disc can be directly observed.

The upper compartment has large medial and lateral recesses which enclose the lower compartment. Therefore, after filling upper compartment with radiopaque contrast material much of the lower compartment will be obscured during transcranial radiography. The interpretive difficulties deriving from superimposition of the joint compartments resulting from the application of lateral oblique transcranial projection was also pointed out by Frenkel (1965) who advocated arthrography with tomography. Arthrography with injection of contrast medium into both joint compartments has later on been performed with tomography (Kraszewski et al. 1972; Wilkes 1978 a,b; Blaschke 1980; Blaschke et al. 1980; Katzberg et al. 1980 a,b; Blaschke 1981; Bronstein et al. 1981). This way details in one plane are selectively visualized while details of adjoining planes are eliminated and the interpretation of the arthrograms greatly facilitated.

Tomography is also advantageous in producing radiographic images of different portions of the joint. This was found to be valuable since a frequent observation was different position as well as different configuration of the disc in the lateral, central and medial thirds of the joint. In simultaneous tomography (Schönberger 1957, Mazaheri & Biggerstaff 1967, Omnell 1980) the different sections of the joint are depicted

simultaneously during one exposure which ensure correct interlayer distance and unchanged joint position. Simultaneous tomography also reduces the radiation dosis and time of examination.

Hypocycloidal tomographic movement provides high perfection in blurring (Davidsen 1971) and was used since in temporomandibular joint arthrotomography the object of examination is small and contains minute structures of great clinical importance.

A disadvantage of the tomographic technique, however, is its disability to depict the most lateral and most medial parts of the joint (Eckerdal 1973; II;V). As the lateral part of the temporomandibular joint is most frequently exposed to osteoarthritis (Öberg et al. 1971; VII) and to changes in position and configuration of the disc (VII), depiction of this part of the joint is essential for the diagnosis. Lateral oblique transcranial radiography provides a radiographic representation of the most lateral part of the joint and this disadvantage of tomographic technique may be overcome by performing transcranial arthrography after injection of contrast medium into the lower compartment as described by Farrar & McCarty Jr (1979 b), Murphy (1981), Murphy & Adams (1981). This complementary radiographic procedure should demonstrate the position of the disc most laterally and decrease the number of false-negative reports.

In an experimental study on autopsy specimens (II) the diagnostic accuracy of double-contrast arthrotomography was found to be close to 80%. Since function of a joint is essential for diagnosis a higher diagnostic accuracy may be expected clinically by obtaining arthrotomograms at several condylar positions than in these single picture examinations of stationary autopsy specimens.

This assumption is in accordance with results of Mulder & Laskin (1980). In an experimental study on baboons they found that arthrotomograms obtained at three different condylar positions demonstrated induced internal derangements consistently with surgical observations. Knowledge of joint anatomy, and of pitfalls as well as attention to details may further improve the diagnostic accuracy of double-contrast arthrotomography. Thereby the accuracy may increase from about 80% to more than 90% as found in several large series of double-contrast arthrographies of the knee (Freiberger et al: 1966; Butt & McIntyre 1969; Nicholas et al. 1970; Dalinka et al. 1973). The interpretation of the arthrograms obtained from patients was greatly facilitated by the experience from the autopsy specimen examinations. Feedback from subsequent surgical observations will also improve the diagnostic ability.

Double-contrast arthrography was attempted with cine-radiography but was not successful. The small amount of radiopaque contrast medium used in double-contrast arthrography did not produce a sufficient definition of the inferior surface of the disc. Therefore, for cineradiography double-contrast in the upper compartment was combined with single-contrast in the lower compartment. This combination produced a well defined image of the intra-articular anatomy at cineradiography of autopsy specimens.

Temporomandibular joint clicking

The following findings indicate that the mechanism of clicking in the autopsy specimens was the same as in patients:

- identical clicking sound
- clicking in the autopsy specimens is unlikely to be a post mortem artefact as the condyle in joints with-

- out clicking could not be moved, manipulated or forced in order to release the clicking
- the posterior part of the closing condylar path ran inferior to the opening condylar path as found in patients by Farrar (1978)
 - clicking was associated with a bulge in the condylar path as found in patients by van Willigen (1979) and Isberg-Holm & Ivarsson (1980)
 - the condyle - disc relationship in association with reciprocal clicking was the same in autopsy specimens as found in arthrographic examinations of patients (Wilkes 1978 a; Dolwick et al. 1979; Farrar & McCarty Jr 1979 a,b; Blaschke 1980; Blaschke et al. 1980; Katzberg et al. 1980 a,b; Blaschke 1981; V;VI) and at surgery (McCarty Jr 1980; Wilkes 1980; Eriksson 1982).
 - the case history of one of the patients from whom a clicking joint was obtained at autopsy, revealed long standing clicking from the removed joint during the lifetime of the patient.

When arthrography was combined with cineradiography, reciprocal clicking was found to be associated with the condyle sliding under the posterior band of the disc and disc movement in opposite direction to the condylar movement. These findings confirmed arthrographic observations made in patients with clicking temporomandibular joints (Wilkes 1978 a; Farrar & McCarty Jr 1979 a; Katzberg et al. 1980 a,b; V;VI).

In one joint a non-reciprocal clicking was observed. The mechanism of clicking was not completely disclosed, but assumed to be caused by the condyle and disc passing over an obstacle probably on the temporal articular surface. This may be in accordance with suggestions that local thickening of the articular

surfaces could be one cause of clicking as proposed by Steinhardt (1934, 1957), Nanthaviroj et al. (1976), Lysell & Hansson (1977), Isberg-Holm & Ivarsson (1980), Watt (1981).

The arthrographic and cineradiographic study on autopsy specimens did not reveal what actually caused the sound and at what condylar position clicking occurred because the movements were rapid relative to the framing frequency used. In order to investigate this a high-speed technique was made available.

The joints were visualized by a lateral opening on the capsule. In spite of this, clicking occurred. This observation makes the theories, that clicking is due to collapse of vacuum, as was also questioned by Campbell (1963) or changes in movement of the synovial fluid (Yavelow & Arnold 1971) less probable. The high-speed technique used, showed clicking to occur at the instant the condyle, with the disc or posterior attachment in between, impact on the temporal component after rapidly passing the posterior band of the disc (IV). This origin of the sound is in accordance with suggestions made by Steinhardt (1957) although he described the condyle as passing the anterior band of the disc in association with clicking.

Anterior disc displacement in patients

In accordance with recent arthrographic studies (Wilkes 1978 a,b; Farrar & McCarty Jr 1979 b; Blaschke et al. 1980; Katzberg et al. 1980 b; Bronstein et al. 1981) the most frequent finding when applying double-contrast arthrotomography to patients with clicking or with a history of clicking followed by limitation of opening was anterior disc displacement. These findings contradict considerations by Laskin (1969) that there is a low prevalence of organic disease of the temporomandi-

bular joint in patients with the pain dysfunction syndrome. Although not arthrographically identified in the 1940s anterior disc displacement seems to be present both in illustrations (Fig 29, 45) and in the case histories published in Nørgaards comprehensive monograph on temporomandibular arthrography (1947). Also the illustration presented by Toller (1974, Fig 5) seems to show anterior disc displacement.

In patients with clicking, the anteriorly displaced disc was repositioned in association with clicking during opening in accordance with observations in autopsy specimens with clicking (III;IV). In patients with limitation of opening the disc was constantly displaced anterior to the condyle blocking anterior condylar translations. These findings support clinical observations that a temporomandibular joint which clicks is not locked, and a joint that locks does not click.

Different positions of the disc in the lateral, central and medial portions of the joint were seen in patients (V;VI) as well as in autopsy specimens (II; VII). Most common was an oblique position, i.e. anterior position laterally or laterally as well as centrally combined with superior position medially. Oblique position, described by Pringle (1918-1919) and recently described in an arthrographic study (Katzberg et al. 1980 b), was associated with displacement with reduction (V, VI). In joints displaying anterior disc displacement without reduction, the disc was more frequently anteriorly displaced laterally, centrally as well as medially. In joints with oblique disc position the distance between the mandibular and temporal components will be maintained medially. Therefore the lateral part of the disc may alter its position from anterior to superior during opening without strong traction in the posterior disc

attachment. In joints with anterior disc displacement laterally, centrally as well as medially the traction in the posterior disc attachment during opening before clicking and reposition occur, may be stronger than in joints with oblique disc position. This difference may be one of several reasons why clicking in some patients after a few months is substituted by locking, while clicking in others continues for years.

Concerning the etiology of anterior disc displacement the study by Randow et al. (1976) is interesting. They introduced experimentally an unilateral occlusal interference in eight test subjects. In two of them this resulted in clicking, severe irregularities of mandibular movement pattern and severe lateral palpatory tenderness of the temporomandibular joints. Their observation supports suggestions by Farrar & McCarty Jr (1979 b) that one etiologic factor for the development of anterior disc displacement may be "irregular dental occlusal inclines which cause posterior deflection of the condyle". Other etiologic factors have been discussed such as trauma (Katzberg et al. 1980 b) and incoordination between the superior and inferior "components" of the lateral pterygoid muscle (Farrar & McCarty Jr 1979 b). Opposed to these mechanical theories Brown (1980) considered nervous tension and excessive use of the jaw as chief causes of internal derangement. Thus, several different factors have been suggested as causative of anterior disc displacement. Future studies may shed light on which of these factors that are the most important ones.

Compared to patients with clicking the patients with limitation of opening exhibited more pain, more signs of mandibular dysfunctions, more hard tissue changes and higher frequency of perforation and deformation of the disc. It was therefore concluded that anterior disc

displacement without reduction might represent a more advanced stage than displacement with reduction, and may in some cases be a precursor to osteoarthritis. It would be valuable if future research could identify symptoms and signs of those patients with internal derangement that may progress to osteoarthritis.

Internal derangement related to osteoarthritis

Altered position and configuration of the disc were associated with osteoarthritis while biconcave discs in superior position were associated with normal articular surfaces (VII). This supports assumptions that anterior disc displacement in some cases may progress to osteoarthritis (Wilkes 1978 a,b; Farrar & McCarty Jr 1979 b; Katzberg et al. 1980 b; Murphy 1981; VI).

Biconcave discs were most often found superiorly, while one fifth was found anteriorly. Conversely discs of other configurations were generally found in oblique or anterior position. Similar observations were made in patients during arthrography (V). Discs in oblique or anterior position as well as discs of even thickness laterally were associated with osteoarthritis in 50% compared to 90% for biconvex discs. These data indicated deformation of the disc to be a more advanced stage than merely an altered position. One event in the early development of osteoarthritis might be an altered position followed by an altered configuration. However, progression to osteoarthritis, a disease with multifactorial etiology, seemed not to be an inevitable result of altered position since only one-fourth of the anteriorly positioned, but biconcave discs in this autopsy study were associated with osteoarthritis. As osteoarthritis represents "the final pathway" of a variety of mechanisms (Radin et al. 1980), internal derangement of the temporomandibular joint does not necessarily imply the development towards osteoarthritis.

The results of paper VII show an association between altered position and configuration of the disc and osteoarthritis. In a possible progression of internal derangement to osteoarthritis both position and, to a considerable extent, configuration of the disc seems to be involved.

Clinical considerations concerning arthrography of the temporomandibular joint.

It seems clear that arthrography is an effective method for studying the intra-articular anatomy and function of the joint. The arthrographic procedure may also be of value in differential diagnosis of unclear facial and head pain as pointed out by Wilkes (1978 a).

In the beginning of this study indications for arthrography included symptoms and signs of internal derangement of the temporomandibular joint such as clicking and locking. Later on, patients with characteristic reciprocal clicking indicating anterior disc displacement with reduction were diagnosed and treated without an arthrographic diagnosis. On the other hand, during the course of this study we become more aware of patients with a history of clicking, sometimes many years ago, followed by transient limitation of opening. Such history may indicate anterior displacement without reduction and with a considerable deformation of the disc.

In clinical work indications for arthrography of the temporomandibular joint must be related to the therapeutic possibilities that may evolve as a result of information produced by arthrographic examination. Conservative treatment of temporomandibular joint disorders can usually be performed without an arthrographic diagnosis. Since no study has been performed that shows treatment based on arthrographic diagnosis

to be superior to that based on other diagnostic methods, there are hardly indications for arthrography in cases of conservativ treatment. When conservative therapy has failed and surgical intervention is contemplated, arthrography should be performed. Arthrography may be the rational basis, i.e. an accurate diagnosis, for surgical procedures applied to the temporomandibular joint which has been lacking in the past years (Omnell 1980). It should be born in mind that position and configuration of the disc usually are not obvious at surgery due to the small dimension of the entrance and the lack of a sectional view of the relationship between the joint components. The arthrographic procedure should demonstrate position as well as configuration of the disc in the lateral, central and medial portions of the joint. This information is essential when considering different methods of surgical treatment, such as repositioning of the disc (Annandale 1887; McCarty Jr & Farrar 1979), high condylectomy (Henny & Baldrige 1957; Henny 1969), arthroplasty (Dingman & Grabb 1966), extirpation of the disc (Lanz 1909; Boman 1947; Brown 1980; Carlsson et al. 1981) or condylotomy (Tasanen & von Konow 1973).

As a research tool, arthrography of the temporomandibular joint may be valuable for selection of patients as well as for follow-up examinations in the evaluation of both conservative and surgical methods of treatment.

CONCLUSIONS

1. Double-contrast arthrotomography of temporomandibular joint autopsy specimens allowed an excellent depiction of the disc and joint compartments.
2. The diagnostic accuracy of double-contrast arthrotomography of temporomandibular joint autopsy specimens was close to 80% in this sample. When this technique is complemented with transcranial arthrography and when the knowledge of joint anatomy and of pitfalls is increased, the diagnostic accuracy should be further improved.
3. In association with clicking the condylar path demonstrated an inferiorly directed bulge and the condylar velocity was increased. The bulge in the condylar path in association with clicking was formed when the condyle slipped under the posterior band of the disc but could also be created when the condyle and disc passed an obstacle on the temporal articular surface.
4. Clicking occurred at the instant the condyle impact on the temporal component with the disc or posterior attachment in between. All joints with clicking exhibited remodellings but none osteoarthritis.
5. Clinically, double-contrast arthrotomography of the temporomandibular joint clearly demonstrated the position and configuration of the disc with its anterior and posterior attachments. The articular surfaces and outline of the joint compartments were demonstrated in an informative way. Normally the disc was located superior to the condyle. The most frequent internal derangement was anterior displacement of the disc.

6. Clicking or a history of clicking unveiled themselves in our sample as features of anterior disc displacement. Differences of both clinical and radiological observations in patients with clicking compared to those with limitation of opening might justify two different diagnoses, displacement with and without reduction.

7. Oblique and anterior position as well as deformation of the disc was associated with osteoarthritis. In a possible progression of internal derangement to osteoarthritis not only position but also to a considerable extent, the configuration of the disc might be involved.

8. Arthrography of the temporomandibular joint is indicated when symptoms and signs indicate internal derangement, conservative therapy has failed and surgery is contemplated. Arthrography may also be of value in differential diagnosis of unclear facial and head pain.

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DOUBLE-CONTRAST TOMOGRAPHY OF THE TEMPOROMANDIBULAR JOINT

A new technique based on autopsy specimen examinations

P.-L. WESTESSON, K.-Å. OMNELL and M. ROHLIN

Muscular and articular disorders of the stomatognathic system are prevalent (HANSSON & NILNER 1975, HELKIMO 1979, SOLBERG et coll. 1979), and often exhibit symptoms related to the temporomandibular joint. For this reason, radiographic examination of this joint is a common diagnostic procedure. Conventional radiography, tomography included, may reveal changes in shape, structure and function of the skeletal parts of the joint. However, abnormalities are often located in the soft tissues of the joint (STEINHARDT & LANGEN 1933, BLACKWOOD 1963, MOFFETT et coll. 1964, CARLSSON et coll. 1968, ÖBERG et coll. 1971, LINDVALL et coll. 1976, BEAN et coll. 1977, HANSSON & ÖBERG 1977) and these abnormalities are not readily demonstrated with conventional radiographic techniques. Perforation and displacement of the disc are usually not demonstrated.

In order to gain information of the soft tissue components, NØRGAARD (1947) used temporomandibular arthrography with an iodine contrast medium. However, this method has found a limited application only, probably due to the difficult injection technique. During the last decade, however, renewed interest for the method has appeared (AGERBERG & LUNDBERG 1971, CHAO-CHÜ et coll. 1973, TOLLER 1974, LYNCH & CHASE 1978, WILKES 1978a, b, KATZBERG et coll. 1979, FARRAR &

MCCARTY 1979). Double-contrast examination has been widely applied to other joints, such as the knee (ANDERSON & MASLIN 1974, THIJN 1976, FIROOZNIJA et coll. 1976, DALINKA et coll. 1977, HORN 1977, ROEBUCH 1977), the shoulder joint (GOLDMAN & GHELMAN 1978), and the elbow (ETO et coll. 1975). The information yielded by the application of this technique was by ETO et coll., HORN and GOLDMAN & GHELMAN considered to be superior to that resulting from the use of single contrast arthrography.

A technique for double-contrast examination of the temporomandibular joint was described by ARNAUDOW et coll. (1968) and ARNAUDOW & PFLAUM (1974). A small amount of iodine contrast medium followed by a larger amount of air was injected into the joint compartments. The authors indicated the diagnostic value of early recognition of cartilage abnormalities in the joint demonstrated with this technique.

Various procedures for double-contrast examination of the temporomandibular joint have been tested in anatomic specimens, which led to a modification of the technique described by ARNAUDOW et coll. and ARNAUDOW & PFLAUM. The modified technique is now described.

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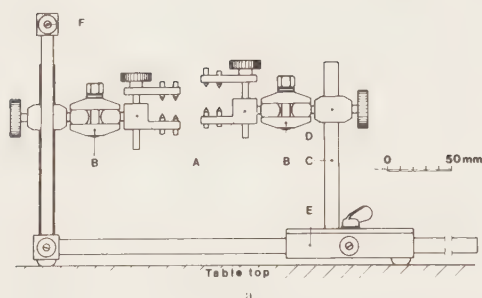
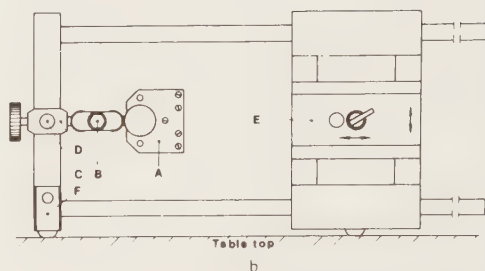


Fig. 1 Positioning device for temporomandibular joint specimens (schematic). a) Lateral aspect b) superior aspect. For lateral tomography the device is placed in the position shown in (a). For a.p. tomography, the device is rotated 90° around its long axis bringing the supporting leg (F) in contact with the top of the tomographic table (b). A—Holders consisting of metal plates carrying pointed pins for fixation of temporal bone and mandibular



lar ramus. B—Double ball-and-socket joints. C—Rods with movable holders (A) and double ball-and-socket joints (B). D—Displaceable sleeves carrying the ball-and-socket joints and holders. E—Cross-guided unit for positioning the condyle in relation to the temporal portion. (In the superior aspect, the right holder and the double ball-and-socket joint have been excluded to facilitate demonstration of the cross-guided unit.) F—Supporting leg.

Anatomy of the temporomandibular joint

A thorough knowledge of the anatomy of the temporomandibular joint will facilitate the understanding of the double-contrast tomography and its results. For a more detailed description cf. KREUTZIGER & MAHAN (1975) and ÖBERG & CARLSSON (1979).

The skeletal parts of the temporomandibular joint consist of the fossa and the articular tubercle of the temporal bone, and of the mandibular condyle. The articulating surfaces are primarily comprised of dense collagenous connective tissue, which may become cartilaginous due to functional load. The joint is divided by the disc in two separate compartments, upper and lower. Antero-posteriorly, the upper compartment extends from a border several mm anterior to the most inferior prominence of the articular tubercle to the posterior part of the roof of the fossa. The lower compartment caps the condyle reaching in a more inferior direction on the posterior side than on the anterior side. On an a.p. view, the upper compartment partly covers the lower compartment by a medial and a lateral recess. The posterior wall of the fossa does not take part in the articulation.

The disc is biconcave in the sagittal plane, i.e. thickest anteriorly and posteriorly. On the a.p. view, the disc is semilunar, often slightly thicker medially than laterally. The disc can be divided into a central part which is dense and hard, and a peripheral looser and softer part which merges with the surrounding capsule. The thickness of the disc in the middle part is approximately one mm, anteriorly and pos-

teriorly, approximately 2 and 3 mm, respectively (HANSSON et coll. 1977). Medially and laterally, the disc is firmly attached to the condyle, merging into the capsule anteriorly and posteriorly.

The capsule originates from the temporal bone at the periphery of the articulating joint surface. It extends inferiorly in the shape of a funnel around the mandibular condyle and attaches to the lower part of the condyle and the upper part of the mandibular neck. Anteriorly and posteriorly, the capsule is loose to allow for movements of the mandible. Excessive displacement of the condyle is restricted by the temporomandibular ligament situated in the lateral wall of the capsule. This ligament extends from the lateral inferior surface of the zygomatic arch to the lateral neck of the condyle. The lateral pterygoid muscle passes through the antero-medial part of the capsule inserting into the disc and the condyle.

Material and Methods

Forty-five right temporomandibular joint autopsy specimens were each removed en bloc through the middle cranial fossae. The soft tissue covering the joint capsule was removed before radiography.

A positioning device was constructed to hold the specimen during radiography (Fig. 1). The holders A consisted of metal plates with pointed pins, which were used for fixation of the temporal and the mandibular parts. Orientation of the specimen in the positioning device was made by the aid of double ball-and-socket joints B. The holders and the double ball-and-socket joints A and B could be moved along

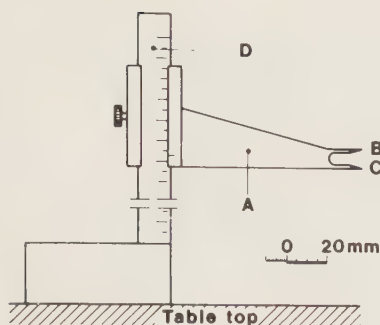


Fig. 2. Indicator device for establishing the levels of tomographic sectioning in simultaneous tomography (schematic). A—Arm movable vertically. B and C—Pointers. The distance between B and C is equal to the distance between the uppermost and lowermost tomographic section obtained in one exposure. D—Scale used for adjustment of the tomographic table.

rods C in order to establish the relation between the temporal and the mandibular parts of the joint specimen. The holder, used for fixation of the mandibular part, was placed in a cross-guided unit E. This unit, which allowed only horizontal movement, was used for examination of the joint in different antero-posterior condylar positions. It was possible to define and re-established each condylar position by using two coordinate axes indicated on the cross-guided unit.

For lateral tomography, the positioning device was placed as in Fig. 1 a. For a.p. tomography, the device was turned 90° bringing the supporting leg F in contact with the top of the tomographic table. The 90° rotation was performed without displacing the specimen.

The joint was punctured with a 14° vein point needle, 0.4 mm×20 mm fixed to a 1 ml syringe graded in 0.01 ml. The lower joint compartment was punctured first. With the condyle in an inferior position, but behind the posterior slope of the articular tubercle, the puncture was made postero-inferior to the condyle. A resistance was felt when the capsule was passed. The needle was then advanced 2 to 3 mm in an upward-inward-forward direction along the posterior surface of the condyle; the needle was slightly tilted so that the posterior surface of the condyle could be felt with the needle tip. After slight withdrawal of the needle, injections were made in the following sequence: 0.5 ml air, 0.10 iodine contrast medium and approximately 0.8 ml air.

Puncture of the upper joint compartment was per-

formed with the condyle positioned inferior to the articular tubercle. The needle was introduced approximately 3 mm behind the condyle at the level of its upper surface. The needle was then advanced almost horizontally inward and forward until the needle tip made contact with the articular eminence. The needle was withdrawn slightly and injections made in a sequence of 0.5 ml air, 0.15 ml iodine contrast medium and approximately 1.0 ml air. Between the injection of iodine contrast medium and the final injection of air into each compartment the condyle was moved frequently, particularly in an antero-posterior direction in order to distribute the contrast media in the joint spaces.

The first 22 joint specimens were injected with Urografin 60% (sodium and methylglucamine diatrizoate; 292 mg I/ml). The remaining 23 were injected with Conray (iothalamate sodium; 400 mg I/ml). At a temperature of 37°C; the viscosity of Urografin 60% and Conray is 4.4 mPa·s and 4.5 mPa·s, respectively. In order to maintain a uniform viscosity throughout, the syringe with contrast medium was placed in 37°C water for 10 min.

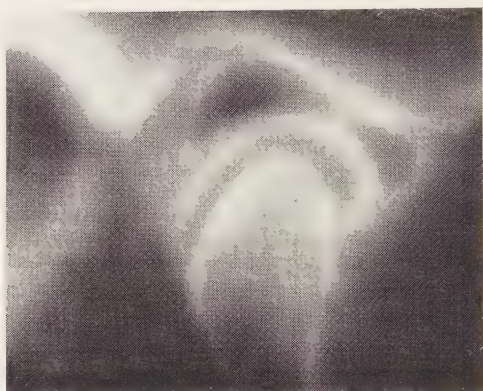
Radiography

The apparatus used for this investigation was a Philips Universal Polytome equipped with a Siemens Biangulix roentgen tube 150/30/50R; hypocycloidal movement; FFD 1.465 m; focus size 0.6 mm×0.6 mm, magnification factor 1.3; exposure data: 60 kV, 20–33 mA, 6 s. The diameter of the cross-section of the beam in the tomographic plane was 42 mm. No grid was used. The radiographic examination was performed approximately 3 min after the puncture procedure and the injections.

Simultaneous tomography was performed using a multi-film cassette containing 5 pairs of intensifying screens (Siemens Verstärkerfolien, Simultan) and 5 films (Ilford Rapid R) covering a total tissue layer of 10.5 mm. Thus, the interspace between the different tomographic sections was 2.5 mm.

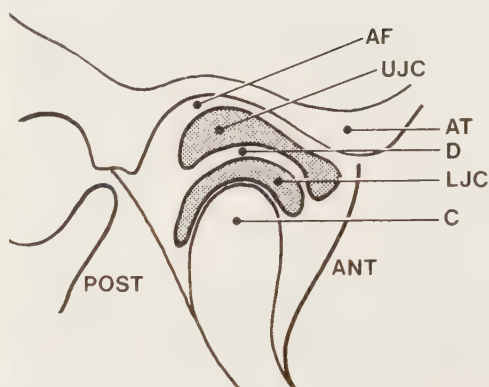
An indicator device was used for establishing the level of sectioning (Fig. 2). After placing the device on the table top, the arm A was adjusted in relation to the specimen. The two pointers B and C indicated the uppermost and lowermost tomographic sections, respectively, which were obtained in one exposure. The tomographic table was adjusted so that its measurements were identical to those indicated on the scale D of the indicator device.

Two directions of tomographic sectioning were



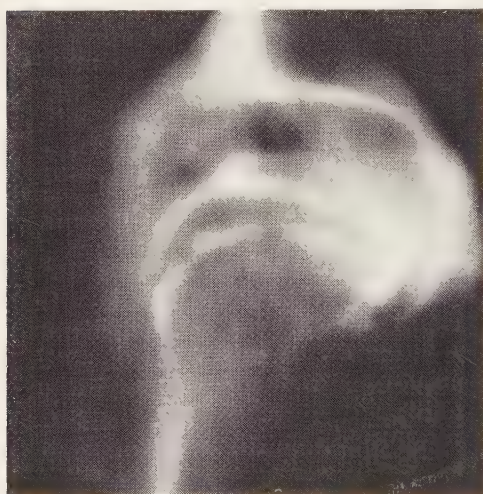
a

Fig. 3. a). Lateral double-contrast tomography. The central part of a temporomandibular joint specimen. The condyle is placed inferiorly in the fossa. Upper joint compartment has a slight sigmoid shape and is located more anteriorly than the lower compartment. The latter is of uniform width and is capping the condyle. On the posterior surface of the condyle, the lower com-



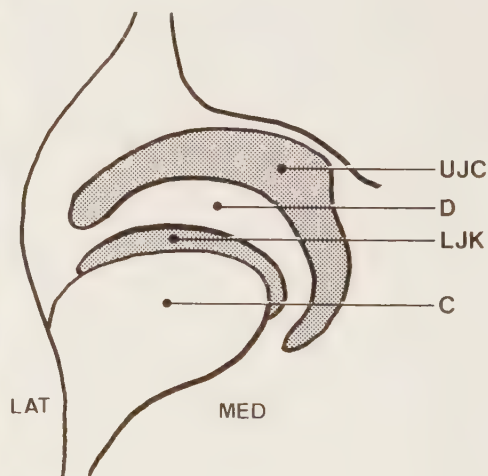
b

partment reaches further inferiorly than on the anterior surface. The disc is separated from the mandibular and temporal component. b) Schematic drawing of (a). AF—Articular fossa. UJC—Upper compartment. AT—Articular tubercle. D—Disc. LJC—Lower compartment. C—Condyle. ANT—Anteriorly. POST—Posteriorly.



a

Fig. 4. a) A.p. double-contrast tomography. Central part of a specimen. The condyle is placed inferiorly in the fossa. Both joint compartments have a crescentic appearance. Medially, the upper joint compartment embraces the lower joint compartment. Later-



b

ally, the disc is attached to the lateral convexity of the condyle, medially more inferiorly. b) Schematic drawing of (a). UJC—Upper compartment. D—Disc. LJC—Lower compartment. C—Condyle. LAT—Laterally. MED—Medially.

employed: lateral, perpendicular to the long axis of the condyle, and a.p., parallel to this axis.

Lateral tomography. Two exposures were made using the multi-film cassette. The table was moved 10 mm vertically between exposures. An average

condyle has a latero-medial dimension of approximately 20 mm (ÖBERG et coll.). Thus, the series of 10 tomograms obtained were distributed approximately throughout the latero-medial dimension of the joint.

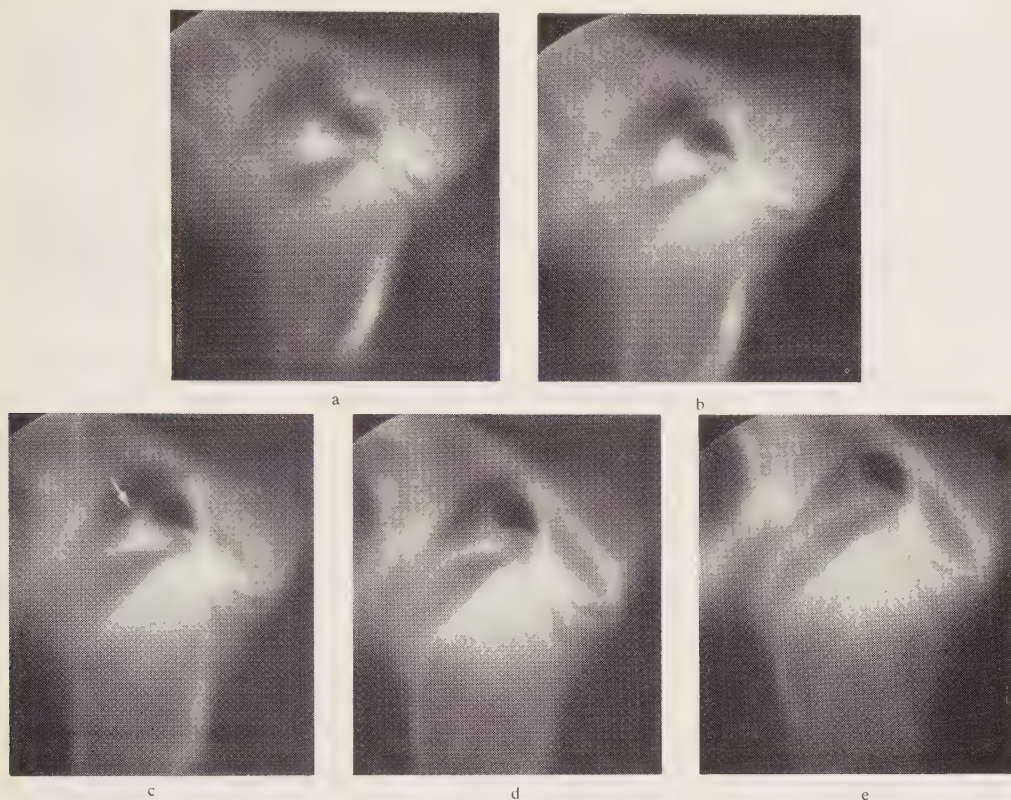


Fig. 5. Lateral double-contrast tomography. Series of films from one exposure. a) Most lateral view and e) most medial. Distance between each tomographic layer 2.5 mm. The shape of the disc and joint compartments depends on the tomographic layer. Due to local contact between the articular tubercle, the disc and the condyle in the area where the supero-anterior surface of the condyle opposes the posterior slope of the tubercle, the two joint compartments are each seemingly divided into two chambers,

one posterior and one anterior. In all sections, the upper joint compartments have a fairly similar appearance. In a medial direction, the lower joint compartment deepens considerably in the posterior part. The lateral part of the disc has a fairly even thickness (a) while the medial part is biconcave (d). The circular area in the posterior attachment of the disc (c) is caused by an accidental deposit of contrast medium (→).

Antero-posterior tomography. When the lateral tomography was completed, the positioning device was turned 90°, placing the long axis of the condyle parallel to the table top, i.e. to the plane of sectioning. The condyle was placed slightly posterior to the articular eminence. Two exposures were made which were 10 mm apart. The average antero-posterior dimension of the joint is approximately 20 mm (ÖBERG et coll.). The resulting 10 tomograms demonstrated an antero-posterior dimension of the joint containing the condyle as well as the structures situated slightly anteriorly and posteriorly.

The films were developed in an Ilford Rapid R

200 automatic processor. After the radiographic examination, the joints were fixed in 10% neutral formalin.

Results

In 40 specimens it was possible to inject both compartments of the joint. The remaining 5 were only injected in one compartment as the other was accidentally opened during removal of the specimens at autopsy. Of the 40 specimens, it was impossible to evaluate the resultant films of 3 specimens due to extensive extra-articular deposits of the iodine contrast medium.

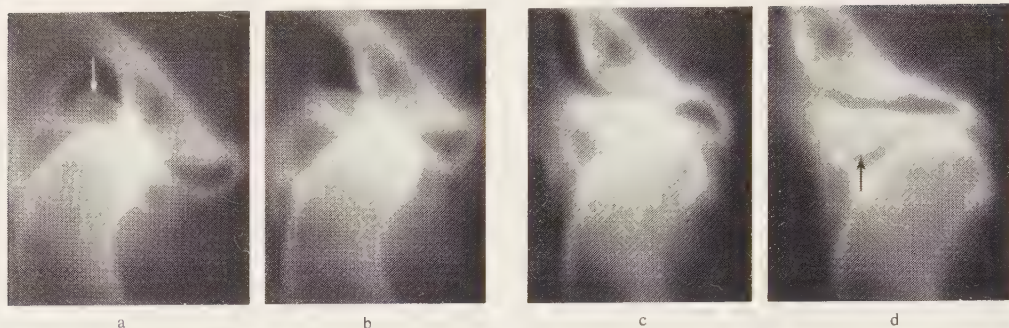


Fig. 6. Lateral double-contrast tomography. Same tomographic layer of the central part of specimen. The shape of the disc and the joint compartments depends on the position of the condyle. a) Condyle is in low position behind the articular tubercle, the disc is biconcave with a cranial convexity in its posterior part ($\rightarrow$). The

joint compartments are rounded. b—d) Condyle is moved anteriorly step by step, the disc obtains a biconvex form with a posterior caudal convexity ($\rightarrow$). The joint compartments are stretched along the articular tubercle and the condyle (d).

Examples of lateral and a.p. double-contrast tomography are illustrated in Figs 3 and 4. The lateral view (Fig. 3 a) demonstrates the central part of the joint with the disc well separated from the temporal part and from the condyle. The thickness of the disc was uniform except for the areas of attachment. The walls of the 2 compartments are outlined by the contrast medium. Immediately after injection, the contrast medium was confined to the walls of the joint compartments, but gradually penetrated through the soft tissues. On the a.p. view (Fig. 4 a), the outline of the joint is not as well defined as on the lateral view. However, the disc is clearly separated from the other joint components.

The appearance of the joint compartments and the disc depended upon the level of sectioning (Fig. 5) and the position of the condyle (Fig. 6) as well as upon the amount of air injected. The best over-all view of the walls of the joint compartments was obtained from the middle third of the joint both in the lateral and the a.p. views when the condyle was positioned inferiorly in the fossa (Figs 3, 4).

Frequently, a local contact between the articular tubercle, the disc and the condyle was observed (Figs 5, 6). Occasionally, this contact was maintained in the whole series of lateral films of the same joint. However, mostly the joint parts were separated at least in the medial third of the joint.

Upper joint compartment. Due to the local contact between the articular tubercle and the disc, this compartment appeared as 2 chambers on many lateral tomograms.

When the condyle was located behind the articular eminence, the posterior chamber was generally more distended by air than the anterior one (Figs 5, 6). At anterior position of the condyle, both the posterior and the anterior chambers became elongated and narrow (Fig. 6). In an extreme anterior position of the condyle the entire upper compartment appeared as a thin space along the tubercle (Fig. 6 d). On a.p. views, the width of the compartment appeared uniform except for the lateral and medial areas (Fig. 4 a). The upper compartment often extended more caudally embracing the lower joint compartment.

The disc. Generally, it was possible to demonstrate the disc with a very good definition particularly at lateral tomography. The appearance of the disc varied considerably, not only between tomographic layers (Fig. 5) and different specimens (cf. Figs 3–5), but also between different positions of the condyle. Fig. 6 illustrates a drastic change in the shape of the disc when the condyle had an anterior position. In some joints, the shape of the disc was biconcave in some sections (Fig. 5 c), and in others it exhibited a rather uniform thickness (Fig. 3 a). At a.p. tomography, it was often difficult to obtain a definite outline of the disc. However, its shape and attachment to the lateral and medial poles and of the condyle appeared clearly (Fig. 4 a).

Lower joint compartment. This compartment covered the condyle in a cap-like fashion on both lateral and a.p. views (Figs 3, 4) with the posterior part extending further caudally than the anterior part. In

the central and medial parts of the joint, the posterior part was shallower than in the lateral part (cf. Fig. 5 a, e).

Due to the local contact between the condyle and the disc, which was frequently observed on lateral views, this compartment seemed to be divided into a posterior and an anterior chamber. The posterior chamber, sometimes balloon-like (Fig. 6b), was easier to distend than the anterior one. The anterior chamber appeared cleft-shaped (Fig. 5) or sac-like (Fig. 6 a). The more anteriorly the condyle was positioned, the narrower was the lower compartment.

Discussion

The results indicate that it was possible to obtain double-contrast tomograms of good quality of temporomandibular joint specimens. It was also possible to demonstrate the interaction between condylar position, different levels of tomographic sectioning and disc configuration.

Tomography appears to be the most reliable method for radiographic examination of the temporomandibular joint (KLEIN et coll. 1970, ECKERDAL 1973, GONCALVES et coll. 1974, MARKOVIC & ROSENBERG 1976, OMNELL & PETERSSON 1976, STANSON & BAKER 1976, BEAN et coll., LINDVALL et coll.). The combination of double-contrast examination and tomography allowed detailed demonstration of the soft tissue components of the joint. The technique of ARNAUDOW et coll. and ARNAUDOW & PFLAUM was modified by initial administration of a small amount of air, which greatly facilitated the following injection and distribution of the iodine contrast medium. The lower joint compartment was injected first, since it was partially covered by the upper compartment which, when distended by air, encroaches upon the lower compartment making the injection more difficult.

Urografin 60% and Conray have approximately the same low viscosity. Since Conray has a higher iodine content, 400 mg I/ml against 292 mg I/ml for Urografin 60%, it was used in the final 23 examinations. However, no appreciable difference in relation to the type of contrast medium was found.

Conray was also employed by ARNAUDOW et coll. and ARNAUDOW & PFLAUM. The amount of contrast medium injected was reduced from 0.5 to 0.15 ml and 0.5 to 0.10 ml for the upper and lower compartments, respectively, during examination of the in-

ital 10 specimens. It was felt that the smaller amounts of medium provided a better radiographic image of the joint compartments.

Double-contrast examination of the temporomandibular joint requires a thorough knowledge of its anatomy. The evaluation of the films was facilitated by inspection of the dissected joints.

The procedure is presently being introduced in the clinical practice in patients with temporomandibular joint disorders.

SUMMARY

Double-contrast tomography was applied to temporomandibular joint autopsy specimens. Both joint compartments were given successive injections of air-iodine contrast medium-air. Tomography was performed in lateral and a.p. projections using a multi-film cassette. The shape of the disc and joint compartments was well demonstrated. The influence of the tomographic level and the position of the condyle on the appearance of the disc was analysed.

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Paper II

DIAGNOSTIC ACCURACY OF DOUBLE-CONTRAST ARTHROTOMOGRAPHY
OF THE TEMPOROMANDIBULAR JOINT. Correlation between
arthrography and morphology on autopsy specimens using
dissection and cryosectioning.

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ABSTRACT

Findings from double-contrast arthrotomograms of 52 temporomandibular joint autopsy specimens were correlated with the morphology as seen at dissection or cryosectioning. Arthrotomographic diagnosis was confirmed in 41 joints signifying a diagnostic accuracy of 79%. The misinterpretation that appeared concerned configuration of the disc in three joints, position of the disc in seven joints, and configuration and position in one joint. False-positive reports due to observation errors or insufficient examination can be avoided with improved knowledge of the joint anatomy and pitfalls as well as with increased experience of the technique. False-negative reports due to limitation of tomographic reproduction of the lateral part of the joint can be overcome when double-contrast arthrotomography is supplemented clinically by oblique transcranial arthrography.

INTRODUCTION

Temporomandibular arthrography (1) has recently gained increasing acceptance as a diagnostic tool for evaluation of internal derangement such as a change in the configuration and position of the disc (2, 3, 4, 5, 6, 7, 8). Arthrography with tomography (9, 10) simplifies the interpretation of the arthrograms by eliminating overlapping structures. Based on the superiority of the double-contrast technique for examination of other joints (11, 12, 13) procedures for double-contrast arthrotomography of the temporomandibular joint (TMJ) have been introduced (14, 15).

In spite of difficulties to survey and document the TMJ at surgery, attempts have been made to correlate

arthrographic and surgical findings. The diagnostic accuracy for single-contrast TMJ arthrography has been found to be between 81 and 97% (1, 7, 16). Three examples of disc perforation diagnosed by arthrography but not revealed at surgery are the only specific errors described (6, 7).

A systematic correlation between arthrography and morphology cannot be successfully carried out on patients as only selected TMJ disorders are surgically treated. Furthermore, a positive arthrogram is usually one of the prerequisites for surgical intervention. Therefore, the detection of false-negative diagnosis is unlikely. A correlative study employing a double-contrast technique has not been found in the literature. This communication, therefore, presents the diagnostic accuracy and errors made in the technique of double-contrast arthrotomography of temporomandibular joint autopsy specimens. Findings were compared between dissection, cryosectioning and arthrotomography of the disc.

MATERIAL

Sixty-one TMJ specimens were removed en bloc from cadavers without infectious diseases. No other attempts were made to be selective. The block was taken from the middle cranial area and measured 10 cm x 8 cm x 6 cm. In all but five cases the right joint was obtained. In one case both left and right joints were removed. Distribution of the material with respect to age and sex is presented in Table 1. In nine specimens the arthrotomographic procedure was unsuccessful due to; insufficient injection of contrast media (four joints), injections of contrast media only into the lower compartment (three joints) and extensive extra-articular deposits of iodine contrast medium (two joints). These nine

joints were excluded from further analysis. The mean age of the nine individuals was 76 years (range 65-92) and for remaining 51 individuals 72 years (range 38-93).

METHODS

The soft tissue covering the capsule was removed and the fresh specimen attached to a positioning device (15). By palpation and inspection in the region posterior to the condyle the approximate direction of the condylar long axis was determined. The specimen was oriented with the condylar long axis perpendicular to the tomographic plane. Double-contrast arthrotomography was performed with the condyle in the fossa. In the present study this included injections of iodine contrast medium and air into both compartments followed by serial lateral tomography, depicting nine tomographic layers with 2.5 mm intervals. The level of tomographic sectioning was established with an indicator device. Radiographic equipment, exposure data and indicator device are described by Westesson et al. (15). The first 49 joints were examined by an arthrotomographic technique described by Westesson et al. (15). The remaining twelve joints were investigated with a modified technique, now used for examination of patients (16). The modification included replacement of iodine contrast medium Conray (iothalamatesodium 400 mg I/ml) by Amipaque (metrizamid 300 mg I/ml), replacement of vein point needles by cannulas and changing the sequence of injections from air - Conray - air to Amipaque - air.

Interpretation of Double-Contrast Arthrotomograms

The radiographic appearance of configuration and position of the disc for each joint were interpreted simul-

taneously by the authors and the findings were recorded. The configuration of the disc was classified into four groups; biconcave, biconcave with lateral thinning, of even thickness or biconvex. The position of the disc was classified with the condyle in the fossa into three groups:

- Superior position; the posterior band (i.e. the posterior thick part anterior to the bilaminar zone) of the disc superior to the anatomically most superior point of the condyle and the central thin part of the disc between the posterior slope of the tubercle and the condyle (Fig. 1).
- Anterior position; the posterior band of the disc anterior to the anatomically most superior point of the condyle and the central thin part of the disc inferior to the posterior slope of the tubercle (Fig. 2).
- Oblique position; superior position medially and anterior position laterally in the joint.

Perforation of the disc was diagnosed by opacity of the upper compartment after injection of contrast media into the lower compartment. Fibrous ankylosis was diagnosed when the free flow of contrast media injected was replaced by several small well defined pools of contrast media between the condyle and the temporal component. Fibrous ankylosis was distinguished from extra-articular deposits of contrast media by the location and appearance. Extra-articular deposits of iodine contrast medium were generally not located close to the bone and appeared as a single radiopacity with a diffuse boundary (Fig. 2).

Dissection

Dissection followed interpretation of the double-contrast arthrotomograms of the first 40 joints. The joints were studied simultaneously by the authors and their observations recorded. The temporal component was separated from the disc and condyle by a circumferent incision in the capsule into the upper compartment.

Lower compartment was opened laterally, anteriorly and medially. Without detaching from the condyle posteriorly, the discs were sagittally sectioned into a lateral, central and medial third. This facilitated the study of the anteroposterior relation between the posterior band of the disc and the anatomically most superior point of the condyle. Configuration and position of the disc were classified according to the criteria presented for interpretation of double-contrast arthrotomograms.

Cryosectioning

Immediately after radiography, twelve joints, without being detached from the positioning device, were frozen by repeated application of hexane, cooled to -70°C by carbon-dioxide ice. The joints were embedded in a gel of carboxymetyl cellulose (CMC), then frozen, forming a square support around the specimen. The bottom of the CMC block was parallel to the tomographic plane. On the sides of the CMC block, perpendicular to the tomographic plane, the levels of tomographic sectioning were marked with the indicator device, which was also used for establishing the level of tomographic sectioning. The CMC block was mounted on a large microtome stage and sectioned on a heavy-duty microtome (LKB 2250 PVC Cryo-Microtome PMV 450 MP, Stockholm, Sweden). The method of freezing, embedding and sectioning is described by Ullberg (18). The block was cut in sections 25 μm thick. At intervals of 0.5 mm the newly cut surface of the specimen was photographed, as described for the TMJ by Eckerdal (19) and for the knee by Rauschnig (20). Photographs were taken at a scale of about 1:1 using Kodachrome 25 film and a 35 mm SLR camera (Olympus OM2) equipped with a macrolens (Vivitar Series 1 90 mm F 2.5 macro), a bellow (Olympus autobellow) and an automatic flash unit (Olympus T32). The slides were studied under different magnifications by both authors. Configuration and position of the disc were classified according to the criteria presented for interpretation of double-contrast arthrotomograms.

Comparison between Radiologic and Morphologic Findings

The radiographic appearance of configuration and position as well as perforation of the disc were compared to the morphology made at dissection or cryosectioning of the joint. When radiologic interpretation differed from morphology, the radiographs and specimens were studied once more by the authors in an attempt to explain the disparity.

RESULTS

No appreciable difference of the image quality was registered with respect to the two different arthrotomographic techniques used. The image quality of the resulting double-contrast arthrotomograms was successfully increased during the series of studies. This was done by individual adjustment of the amount of contrast media injected, and by the increasing experience of the examiner.

Table 2 presents the correlation between arthrotomographic and morphologic findings of configuration and position of the disc. In 41 joints the arthrotomographic diagnosis was confirmed at dissection or cryosectioning signifying a diagnostic accuracy of 79%. Figures 1 to 4 illustrate examples in which the arthrotomographic diagnosis was confirmed at dissection or cryosectioning. It was not possible to arthrotomographically determine the position of three discs of even thickness as these did not have a posterior band which was used for determination of the position. At dissection it was found that the dense part of the discs covered the superior surface of the condyle.

In eleven joints there were disparities between arthrotomographic and morphologic findings of configuration

and position of the disc (Table 3). The configuration was misinterpreted in three joints (Fig. 3 C); the position in seven joints and configuration and position in one joint. The errors were grouped into observation errors (two joints), insufficient examination (four joints) and limitation of tomographic reproduction (five joints) (Fig. 3 C). There were six false-positive reports due to observation errors or insufficient examination, whereas limitation of tomographic reproduction resulted in six false-negative reports in five joints.

Eleven disc perforations were diagnosed by opacity of the upper compartment after injection of contrast media into the lower compartment. All perforations were verified at dissection or sectioning. Eight perforations were extensive and definitely demonstrated on double-contrast arthrotomograms (Fig. 4). In two of these joints the perforation involved the entire disc.

During injection the commonly felt passage of the needle through the capsule was not experienced in two joints. The double-contrast arthrotomograms revealed fibrous ankylosis verified at dissection for one joint and at cryosectioning for the second joint.

DISCUSSION

In 41 of 52 TMJs the interpretation of double-contrast arthrotomograms agreed with the morphology. Our results indicated a diagnostic accuracy close to 80%, compared to more than 90% found in several large series of double-contrast arthrography of the knee (11, 21, 22, 23). However, as arthrography of the knee is an established procedure, the diagnostic criteria and the many major pitfalls are well known to those performing that technique (24).

TMJ arthrography has recently gained renewed acceptance but is currently a routine procedure at only a few centers. Our attempt at the beginning of this study was to perform a subjective radiographic interpretation based on recently described diagnostic criteria for normal and anterior disc position (2, 3, 4, 5, 6). This resulted in difficulties for maintaining a consistent observer performance since we found discs in various positions between normal superior and completely anterior. Therefore, the position of the disc was determined by relating the posterior band of the disc to the anatomically most superior point of the condyle which is easily identified both radiographically and morphologically.

In our study, double-contrast arthrotomograms were obtained at one single condylar position. As the function is essential for the diagnosis, tomograms obtained at different condylar positions will contribute to a higher diagnostic accuracy. This is clinically supported by the result of three arthrographic and surgical studies of patients (1, 7, 17). In knee arthrography it has also been pointed out that the diagnostic accuracy increases with the experience of the radiologist (25). If this also holds true for TMJ arthrotomography the false-positive reports could be avoided.

In the present study, errors due to limitation of tomographic reproduction concerned the lateral part of the joint and seemed difficult to avoid. As the lateral part of the TMJ is most frequently exposed to osteoarthritis (26) and to change in configuration and position of the disc (27), depiction of this part of the joint is essential for the diagnosis. The limitation of tomographic reproduction, also found for the mineralized parts of the TMJ, (19) is a disadvantage of the tomographic technique. For this reason clinical double-contrast arthrotomography should be preceded by oblique transcranial arthrography after injection of iodine

contrast medium into the lower compartment as described by Farrar & McCarty Jr.(4). This complementary radiographic procedure depicts the most lateral part of the joint and should decrease the number of false-negative reports.

Morphology of the TMJ was studied employing two different techniques, dissection and cryosectioning. A disadvantage of dissection was that the tomographic inter-relationship between disc and temporal joint component as well as the extension of the joint compartments could not be studied since the components were separated. By applying the considerably more time consuming cryosectioning these disadvantages were overcome. Freezing the specimen immediately after arthrotomography without detaching from the positioning device had the advantage of maintaining the orientation of the specimen and the relationship between the joint components. At freezing a slight expansion of the tissues cannot be avoided resulting in slightly narrowed joint compartments in the cryosection. This minor difference, obvious when comparing the tomogram with the corresponding cryosection, should not influence the results. Injections followed by deep-freezing and radiography were tried but not used in this study as the iodine contrast medium in association with freezing rapidly diffused into the soft tissue, greatly impairing the image quality.

In summary, the diagnostic accuracy of double-contrast arthrotomography of the TMJ was close to 80%. The diagnostic errors were due to observation errors, insufficient examination or limitation of tomographic reproduction. When double-contrast arthrotomography is complemented with transcranial arthrography and the knowledge of joint anatomy and pitfalls is increased the diagnostic accuracy of TMJ double-contrast arthrotomography should be further improved.

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Table 1: Distribution of Age and Sex.

Sex	Age groups (years)					
	-49	50-59	60-69	70-79	80-89	90-99
Female (n = 30)	1	3	3	12	8	3
Male (n = 30)	0	4	7	12	6	1

Table 2: Correlation of Arthrotomographic Diagnosis and Morphology

Arthrotomographic diagnosis of disc		Number of TMJs	Arthrotomographic diagnosis confirmed at dissection/cryosectioning
Configuration	Position		
Biconcave	Superior	11	8
Biconcave with lateral thinning	Superior	3	3
Biconcave	Oblique	5	3
Biconcave with lateral thinning	Oblique	2	2
Biconcave	Anterior	12	7
Biconcave with lateral thinning	Anterior	4	3
Biconvex	Anterior	8	8
Eventhick	Not disclosed	3	3
Perforation occupying entire disc	Not disclosed	2	2
Fibrous ankylosis	Not disclosed	2	2
Total		52	41

Note. - Accuracy $41/52 = 79\%$

Table 3: Disparity between Arthrotomographic Interpretation and Morphologic Findings of Configuration and Position of Disc in Eleven TMJs

Arthrographic interpretation		Morphologic findings		Diagnostic error	Comments	Type of error
Configuration	Position	Configuration	Position			
Biconcave	Anterior	Biconcave	Oblique	Position: false positive medially	Position medially most, not observed. Error obvious at review.	Observation error
Biconcave with lateral thinning	Anterior	Biconcave with lateral thinning	Oblique	Position: false positive medially	Position medially most, not observed. Error obvious at review.	Observation error
* Biconcave	Anterior	Biconcave	Superior	Position: false positive	Poor filling of air due to leakage through capsule.	Unsufficient examination
Biconcave	Oblique	Biconcave	Superior	Position: false positive	Poor filling of air due to leakage through capsule.	Unsufficient examination
Biconcave	Oblique	Biconcave with lateral thinning	Oblique	Configuration: false negative laterally	Tomograms laterally most, revealed no abnormalities.	Limitation of tomographic reproduction
Biconcave	Anterior	Biconcave with lateral thinning	Anterior	Configuration: false negative laterally	Tomograms laterally most, revealed no abnormalities.	Limitation of tomographic reproduction
Biconcave	Superior	Biconcave with lateral thinning	Superior	Configuration: false negative laterally	Tomograms laterally most, revealed no abnormalities.	Limitation of tomographic reproduction
Biconcave with lateral thinning	Superior	Biconcave with lateral thinning	Oblique	Position: false negative laterally	Tomograms laterally most, revealed no abnormalities.	Limitation of tomographic reproduction
Biconcave	Superior	Biconcave with lateral thinning	Oblique	Configuration: false negative laterally Position: false negative laterally	Tomograms laterally most, revealed no abnormalities	Limitation of tomographic reproduction

* This disparity concerned three joints

LEGENDS

Fig. 1. Lateral double-contrast arthrotomography A, with corresponding cryosection photo B, from central third of a TMJ. Condyle is seated in fossa. Upper compartment is seen in fossa and along articular tubercle. Lower compartment covers condyle and has a thin recess anteriorly. The arthrotomographic diagnosis of a biconcave disc in superior position was confirmed at cryosectioning. Posterior band of disc (arrow) superior to condyle and central thin part between condyle and posterior slope of tubercle.

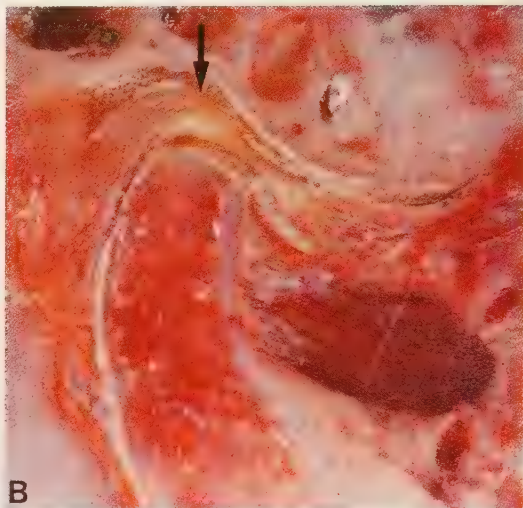
Fig. 2. Lateral double-contrast arthrotomogram A, from central third of a TMJ. In tomogram condyle is seated in fossa. Biconcave disc in anterior position with posterior band (arrow) anterior to condyle and central thin part inferior to posterior slope of tubercle. Accidental deposit of iodine contrast medium in elongated posterior attachment. Corresponding section B, of specimen verifies the arthrographic diagnosis of anterior position of biconcave disc with elongated posterior attachment.

Fig. 3. Lateral double-contrast arthrotomogram A, with corresponding cryosection photo B, of central third of a TMJ. For this part of joint arthrotomographic interpretation of biconcave disc with posterior band (arrow) superior to condyle was confirmed at cryosectioning. Due to limitation of tomographic reproduction no radiographic image of most lateral part of joint was obtained. Therefore even thickness configuration of disc (arrow heads) laterally shown in cryosection photo C, was not radiographically disclosed.

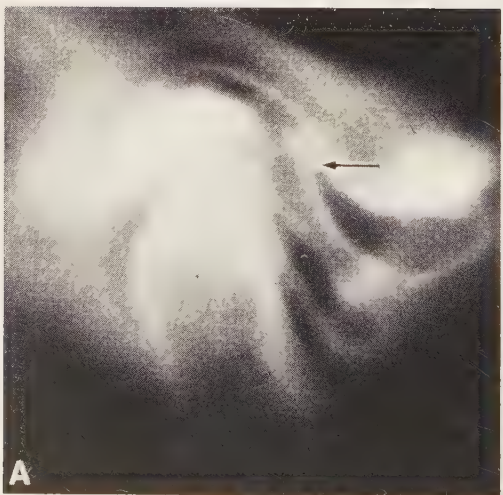
Fig. 4. Lateral double-contrast arthrotomogram A, and corresponding cryosection photo B, from lateral third of a TMJ. Arthrotomographic diagnosis of biconvex disc (arrow) in anterior position and perforation confirmed at cryosectioning. Perforation in posterior attachment clearly demonstrated in cryosection photo B.



A
Fig 1



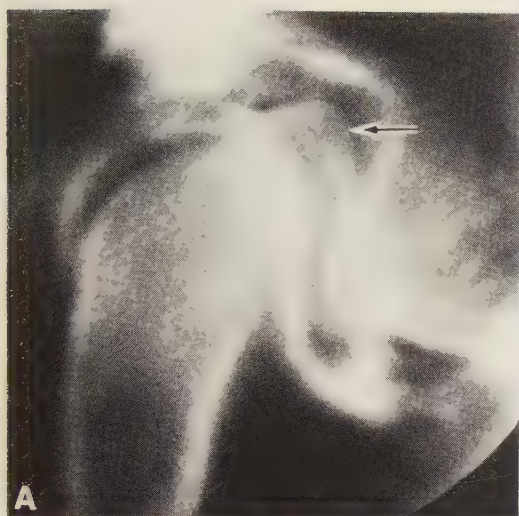
B



A
Fig 2



B

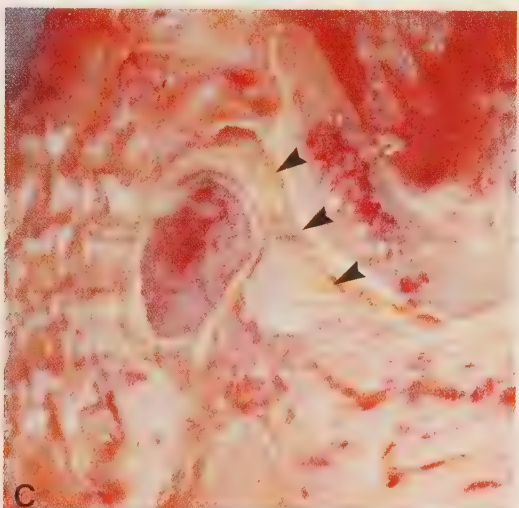


A

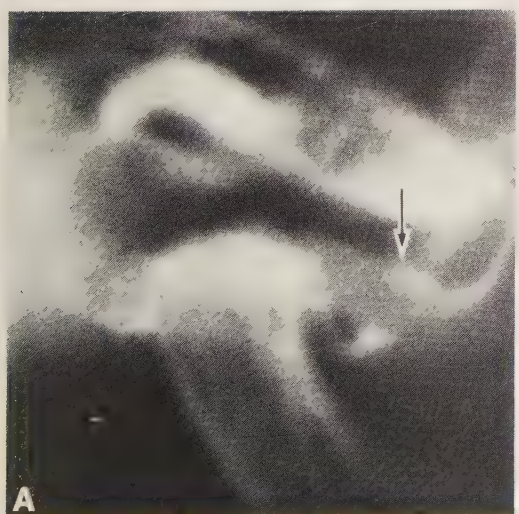
Fig 3



B

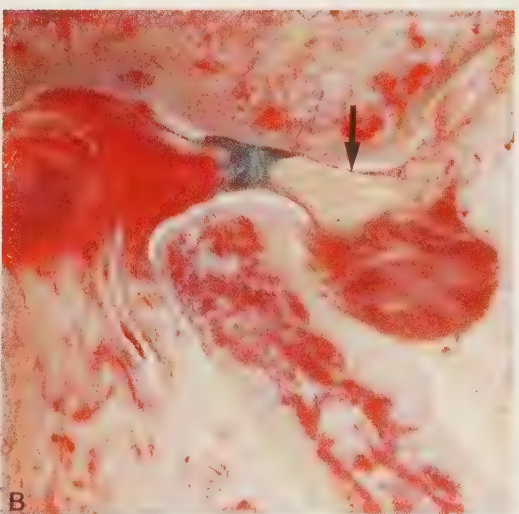


C



A

Fig 4



B

Paper III

Movement of disc and condyle in temporomandibular joints with clicking

An arthrographic and cineradiographic study on autopsy specimens

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Isberg-Holm A. M. & Westesson P.-L. Movement of disc and condyle in temporomandibular joints with clicking. An arthrographic and cineradiographic study on autopsy specimens. *Acta Odontol. Scand.* 1982, 40, 153–166

Arthrography in combination with cineradiography was performed on five temporomandibular joint (TMJ) autopsy specimens with clicking. Clicking was found to be associated with rapid movement of disc and condyle and with a bulge in the condylar path. Clicking and movement in autopsy specimens appeared to be similar to that in patients with TMJ clicking. Four joints demonstrated clicking during protrusion, but this did not occur unless preceded by clicking late during a previous retrusion. In these four joints the disc moved in the opposite direction to the condyle in association with clicking. The findings indicated that the condyle, both at protrusion and retrusion, slipped over the posterior ridge of the disc in association with clicking forming the bulge in the condylar path. In the fifth joint, bulges in the condylar path associated with clicking were registered in the same location both during protrusion and retrusion. In this joint the disc and condyle moved coordinately and were possibly slipping over an obstacle on the temporal articulating surface forming the bulges in association with clicking.

Key-words: Temporomandibular joint function; pathology; autopsy specimens; radiology

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Temporomandibular joint (TMJ) clicking refers to a distinct snapping, cracking sound associated with irregular jaw movement. Clicking may also be associated with pain and locking, symptoms interfering with mastication and speech. Clicking during protrusion has been classified with respect to the occurrence during the early, intermediate or last stage of the movement (4, 12, 38).

Epidemiological studies have indicated prevalences of TMJ clicking in between 14 and 44 per cent of patients (17, 19, 27, 30, 39). Different events leading to clicking have been discussed. For reviews see Rasmussen (35) and Yavelow

& Arnold (49). Deviation in form of articulating surfaces (41, 42) and specifically local thickenings of the articulating tissue layers (31) have been proposed as factors giving rise to clicking.

Condyle and/or disc displacement may also result in clicking. Suggestion has been put forth that the lateral pterygoid muscle pulls the disc forward and out of place with respect to the condyle (34, 38, 40). At such displacements, as well as when the disc slipped into place again, clicking could occur. Clicking during protrusion has been proposed to occur when the condyle slips in front of the anterior ridge of the disc (4, 15, 36, 37,

38, 42). According to Ireland (21), clicking during the final few mm of retrusion was due to the condyle sliding behind the posterior ridge of the disc. During a following protrusion the normal relationship of condyle and disc was not immediately restored. When the condyle eventually overcame the posterior ridge of the disc, the condyle slipped into a correct position below the central part of the disc and another clicking was heard. Farrar (12) acknowledged Ireland's observations, introducing the term reciprocal clicking. In reciprocal clicking, clicking during retrusion will not occur unless preceded by a clicking during protrusion.

Arthrography on patients with clicking has been employed illustrating that prior to protrusive clicking the condyle was located behind the posterior ridge of the disc and after clicking in front of it (10, 13, 14, 46). The results agreed with those of Ireland and with conclusions made by Campbell (7) and Nanthaviroj et al. (31), but contradicts the findings by Toller (44) who also performed arthrography.

Previous radiographic investigations of condylar and/or disc movements associated with clicking have been limited to registrations prior to and after clicking. Recently, however, Isberg-Holm & Ivarsson (23) studied the continuous condylar movement in patients with TMJ clicking, employing an advanced cineradiographic technique. In this way it was possible to obtain a graphic representation of the condylar path during opening and closing movements. A radiographic documentation of the simultaneous movement of both disc and condyle in a clicking TMJ requires a combination of arthrography and cineradiography.

The simultaneous rapid movements of disc and condyle in association with clicking have not been documented in existing literature.

In a study on TMJ autopsy specimens, Westesson, Omnell & Rohlin (45) discovered that some temporomandibular

joints were clicking when the condyle was moved manually in an anterior-posterior direction. The sound appeared to be identical to that in patients with TMJ clicking. These autopsy specimens offered a unique possibility to perform detailed studies on TMJ clicking regardless of radiation dose and other limiting factors pertinent to patients.

The purpose of this study was to investigate the movement of disc and condyle in clicking TMJ autopsy specimens, using a combination of arthrography and cineradiography.

MATERIAL

During a previous study (45) 100 right TMJ autopsy specimens were removed en bloc through the middle cranial fossae. The joints were consecutively numbered from 1 to 100. The TMJs were obtained from 52 males and 48 females, ranging in age from 38 to 93 years with a mean of 73 years. Information about possible TMJ symptoms prior to death was not available. Five joints (Nos 25, 33, 34, 61, 77), removed from five individuals demonstrated clicking when the condyle was moved forward and backward. These five joints were selected for the present study. In the remaining 95 joints it was not possible to move, manipulate or force the condyle in such a way that clicking occurred. Sex, age, number of remaining teeth and presence of dentures at autopsy are presented in Table 1.

METHOD

The soft tissue covering the capsule was removed. The joints were stored at -22°C and thawed to room temperature before radiographic examination.

The radiographic examinations were performed in the following order:
– lateral conventional radiography and

Table 1. Age, sex, number of remaining teeth and presence of dentures in five cadavers from which the TMJ specimens were obtained

Subject No.	Age	Sex	Dental status
25*	84	F	7 maxillary teeth 7 mandibular teeth Upper and lower partial dentures
33	79	M	Edentulous
34	68	F	Upper denture 10 mandibular teeth
61	73	F	Full denture
77	81	M	Full denture

* Patient record revealed long standing clicking from the removed joint during life time.

- lateral tomography to evaluate the structure of the hard tissue
- cineradiography to delineate the condylar path
- cineradiography combined with arthrography to delineate the movements of disc and condyle
- lateral conventional radiography combined with arthrography and double-contrast tomography to evaluate the outline of the joint compartments, in particular the articulating surfaces and the configuration of the disc
- simultaneous graphic sound recording and cineradiography to study the relationship between disc and condylar movements and clicking

Projection

Projection angles between 0° and 20° from above towards the condylar long axis were evaluated prior to this study. At cineradiography in combination with arthrography a projection parallel to the condylar long axis was found to give the

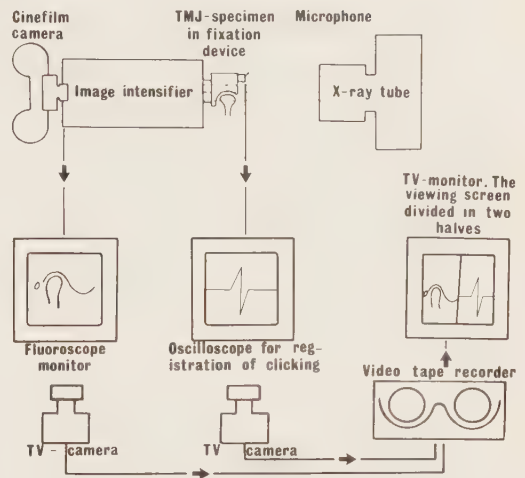


Fig. 1. Diagram of equipment for simultaneous registration of movement of disc and condyle and clicking in TMJ autopsy specimens. The specimen is fixed in a positioning device attached to the image intensifier. In the image intensifier the signal is divided. Radiographic information is recorded by a cine-camera and simultaneously visualized on a fluoroscopic monitor. The monitor image is filmed by a TV-camera. Clicking is registered by a contact microphone, placed on the squama temporalis. The microphone signal is graphically displayed on an oscilloscopic screen, which is filmed by a second TV-camera. The signals from the two TV-cameras are simultaneously recorded on a video tape. When playing the video tape, half the viewing screen visualizes the radiographic image of the movement of the joint components and the other half the graphic registration of the clicking. In this way a simultaneous documentation of movement and sound is obtained.

best reproduction of the disc and articulating surface. This projection was used throughout the entire study.

Positioning device

During radiography the joint specimens were placed vertically in a positioning device (45). Attachment of the device to the different radiographic sets of equipment used, could be reproduced so as to allow the joint specimens to be moved from one set of equipment to another and replaced in the same position. By the aid of the positioning device the joint specimen was placed with the condylar long axis parallel to the central X-ray beam, checked by fluoroscopy and fixed.

Lateral conventional radiography

A lateral single exposure was performed using 50 kVp and 5 mAs. X-ray tube: Siemens Bi 150/30/50 R, focal spot: 0.3 mm, cross section of the beam: 60 mm x 50 mm, screen: Agfa Gevaert MR 200, film: Kodak X-Omat L.

Lateral tomography

Lateral tomography was performed with a Philips Universal Polytome using hypocycloidal movement, 55 kVp and 39 mAs. X-ray tube: SRO 1230, focal spot: 0.3 mm, cross section of the beam: 60 mm x 50 mm. A specially designed cassette for simultaneous tomography was used. It contained three Ilford films (one E and two Rapid R) and five Ilford intensifying screens –two F48EA – SP340, one F51EA – SP340 and two B51BD – SP340). Nine tomograms were obtained with an inter-layer distance of 2 mm.

Cineradiography

The equipment consisted of an X-ray tube, image intensifier, Arriflex cine-camera running 35 mm film and a TV-monitor. The equipment has previously been described by Eliasson & Isberg-Holm (11). In the present study 60 kVp was used. The mAs value was automatically adjusted to achieve an optimal density.

The cine-camera worked with 50 frames/s. The exposed area on the 35 mm film was approximately 6 mm x 5 mm. During cineradiography the condyle was manually moved, corresponding to a full protrusion and retrusion during which clickings occurred. Since this movement to a large extent was guided by capsule, ligaments and the configuration of the joint components it was found to be reproducible.

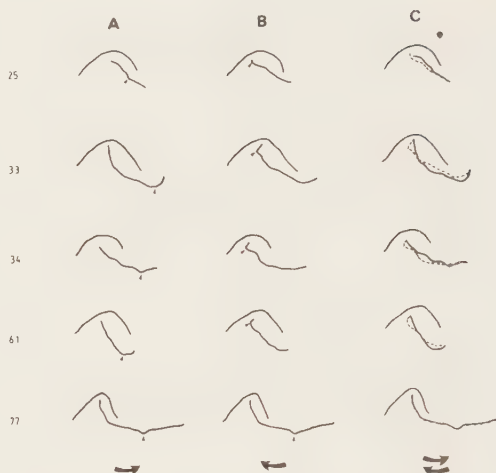


Fig. 2. Tracings from cineradiographic frames of five TMJ autopsy specimens with clicking. The fossa and the condylar path during protrusion (A), retrusion (B) and superimposition of protrusive and retrusive condylar paths (C) are illustrated. A bulge (arrow) in the condylar path was observed in association with clicking. In joints with reciprocal clicking (Nos 25, 33, 34, 61), clicking during protrusion occurred intermediately in one joint (No. 25) and late in three joints (Nos 33, 34, 61). The retrusive clicking in these joints occurred during the posterior part of the movement. The condylar path then described a hook-like path mainly upward. In joint No. 77 the bulge associated with clicking had the same location in the protrusive and retrusive condylar path. Superimposition (C) of protrusive (continuous line) and retrusive condylar path (dotted line) demonstrates that within joints with reciprocal clicking (Nos 25, 33, 34, 61) the posterior part of the retrusive condylar path runs inferior to the protrusive. In the remaining joint (No. 77) the condylar paths during protrusion and retrusion are congruent.

Cineradiography and lateral conventional radiography combined with arthrography

Different arthrographic techniques were evaluated prior to this study and the following technique was found to be the most suitable for the purpose of this study. In the upper joint compartment a double-contrast technique was utilized with injection in the following sequence: 0.5 ml air, 0.15 ml Conray (Iothalamate Sodium 400 mg I/ml) and approximately 0.8 ml air. In this way the outlines of the air-filled upper compartment were defi-

ned by a layer of radiopaque contrast medium on the walls. In the lower compartment a single-contrast technique was applied with injection of approximately 0.6 ml Conray (400 mg I/ml) resulting in opacification of the entire compartment.

The arthrographic procedure gave a radiographic separation between joint compartments and disc enabling depiction of the disc during condylar movement.

After injection of the contrast media, cineradiography was performed followed by lateral conventional radiography. Exposure data and position of the joint specimen were identical to those prior to the injection of contrast media.

Double-contrast tomography

The single-contrast used in the lower joint compartment was replaced by double-contrast by aspiration of most of the iodine contrast medium and the injection of air. Tomography was then performed following the previous procedure. The double-contrast techniques designed for the TMJ is described elsewhere (2, 3,

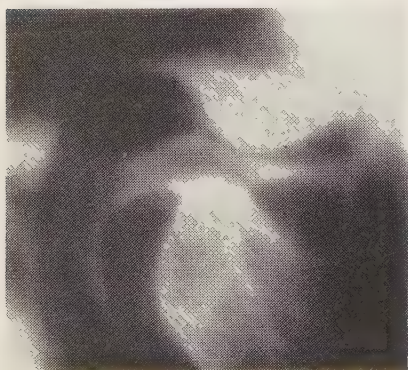


Fig. 3. Graphic oscillographic registration of TMJ clicking in one specimen (No. 61). Left and right amplitudes represent clicking during protrusion and retrusion, respectively. Before and after clicking no distinct sound was registered.

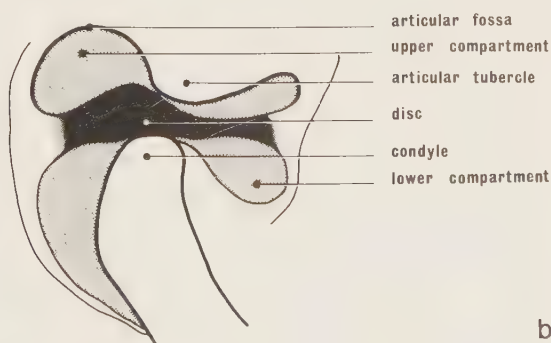
45). In addition one joint (No. 61) was examined with double-contrast tomography during protrusion at condylar positions just before and after clicking.

Simultaneous graphic sound recording and cineradiography

To investigate and document the relation between clicking and movement of condyle and disc, simultaneous graphic sound recording and cineradiography were performed on one randomly selected joint (No. 61). Clicking was registered by a contact microphone (Elema-Schönander EMT 25) placed on the



a



b

Fig. 4 a. Lateral tomogram from the central part of a TMJ autopsy specimen (No. 61) illustrating the radiographic anatomy as seen with a double-contrast technique in the upper and lower compartments. The mandibular condyle is positioned inferior to the articular tubercle. The joint compartments are expanded by air and outlined by a layer of radiopaque contrast medium on the walls. The disc has a biconcave shape. The upper compartment extends from a border anterior to the most inferior prominence of the articular tubercle to the posterior part of the fossa. The lower joint compartment has a deep recess along the posterior surface of the condyle. The anterior recess does not have a corresponding location.

Fig. 4 b. Schematic drawing indicating anatomical landmarks. The dense part of the disc is marked in black.

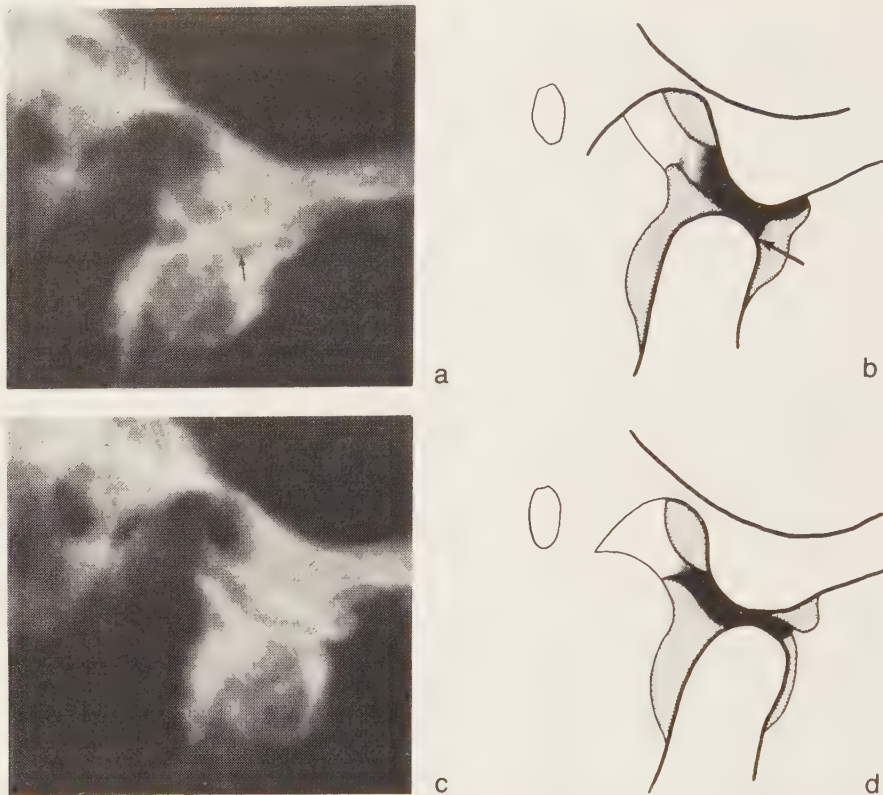


Fig. 5. Cineradiographic frames from a TMJ autopsy specimen (No. 61) with reciprocal clicking. Contrast media has been injected into upper and lower compartments. a) Prior to protrusive clicking. The condyle is located inferior to the articular tubercle. Anterior to the condyle the disc is deformed (arrow). b) Schematic drawing. The dense part of the disc is marked in black. c) After protrusive clicking. The condyle is located somewhat more anterior and the disc more posterior in relation to the condyle. d) Schematic drawing. The dense part of the disc is marked in black.

squama temporalis. The microphone signal was graphically registered by an oscilloscope. The oscilloscopic curve and the cineradiographic image were recorded simultaneously on a video tape. Thus, a simultaneous recording of condylar and disc movements and clicking was obtained (Fig. 1). The technique has been described by Isberg-Holm (22).

Analysis of radiographs

Lateral radiographs and tomograms were interpreted using a viewer according to Mattsson (28), where upon the findings were recorded. The cineradiographic films were analysed in a Tagarno[®] 35.3 analytical projector. The film could be

run forward and backward with variable speed, from stills to 50 frames/s. The condylar path was registered from the film produced prior to the injection of contrast media in the way described by Isberg-Holm & Ivarsson (23). Movement of the disc and its position in relationship to other joint components were studied on the film produced after the injection of contrast media.

RESULTS

Condylar path

The condylar paths are illustrated in Fig.

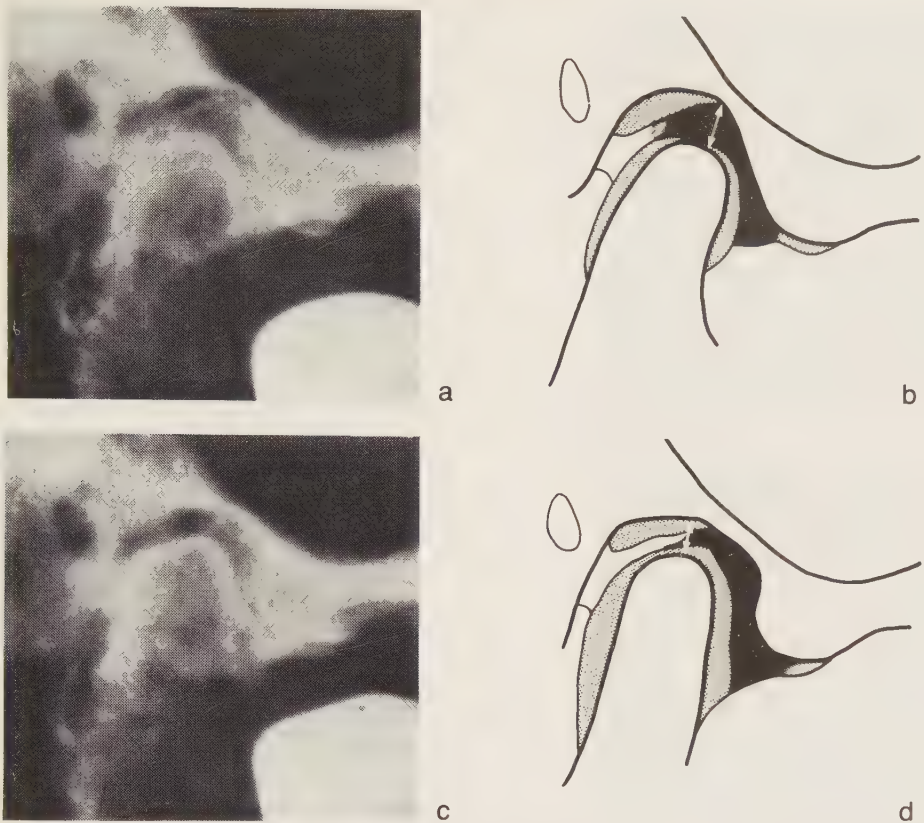


Fig. 6. Cineradiographic frames from a TMJ autopsy specimen (No. 61) with reciprocal clicking. Contrast media has been injected into upper and lower compartments. a) Prior to retrusive clicking. The condyle is located in the fossa with the disc in superior-anterior position. b) Schematic drawing. The dense part of the disc is marked in black. The distance between the condyle and the fossa is indicated with arrows. c) After retrusive clicking. The condyle has moved superiorly (cf arrows in b and d). The disc has moved anteriorly-inferiorly to a position anterior to the condyle. d) Schematic drawing. The dense part of the disc is marked in black. The distance between the condyle and the fossa is indicated by arrows.

2. Clicking was associated with increased condylar velocity and a bulge in the condylar path. The bulge was depicted in as few as three cineframes corresponding to 0.06 s. For each specimen the duration of condylar passage through the bulge seemed to be constant, i.e. it was not influenced by variations in the condylar velocity preceding the bulge. The association between increased condylar velocity, a bulge in the condylar path and clicking was confirmed by simultaneous graphic sound recording and cineradiography in one joint (No. 61). The graphic registration of clicking is seen in Fig. 3,

and illustrates the distinct occurrence of the sound.

Four out of the five examined joints exhibited reciprocal clicking (Nos 25, 33, 34, 61). The clicking during protrusion in three of these joints (Nos 33, 34, 61) was late and in one (No. 25) intermediate. Clicking during retrusion occurred during the posterior stage of the movement. In the fifth joint (No. 77) an intermediate clicking was registered during protrusion. During retrusion clicking occurred as the condyle was located in the same position as during protrusion.

Superimposition of the protrusive and

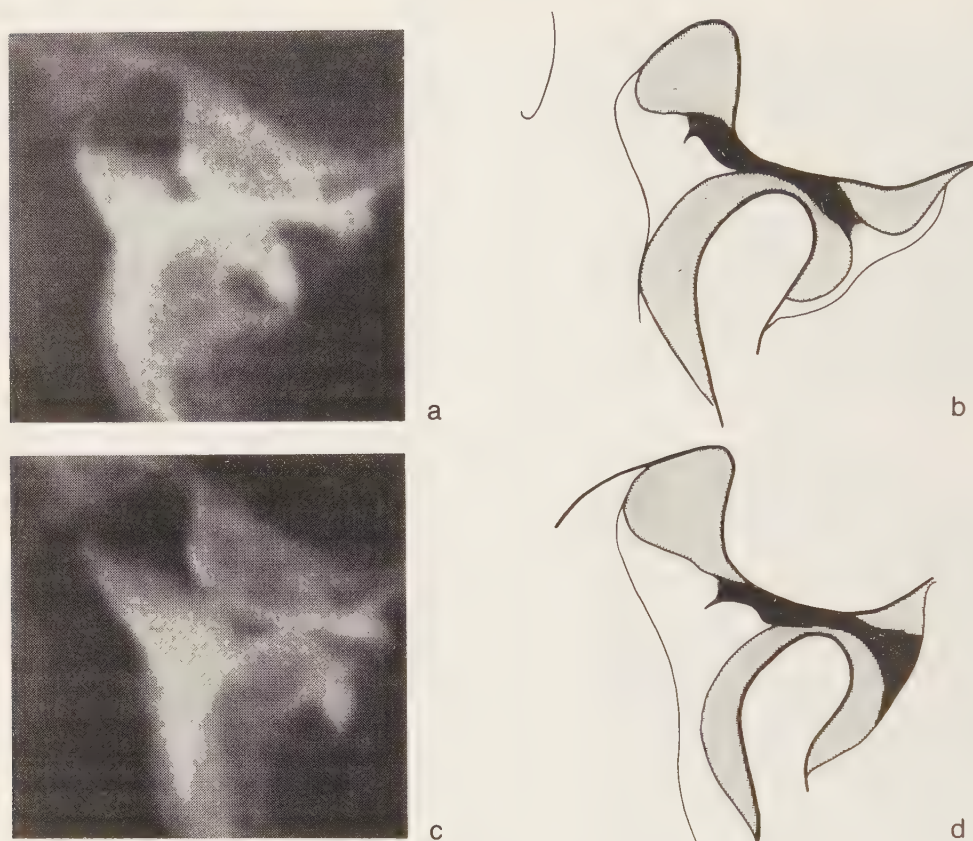


Fig. 7. Cineradiographic frames from a TMJ autopsy specimen with nonreciprocal clicking (No. 77). Contrast media has been injected into the upper and lower compartments. a) Prior to protrusive clicking. The condyle is located inferior to the articular tubercle with the central thin part of the disc in superior position. b) Schematic drawing. The dense part of the disc is marked in black. c) After protrusive clicking. Condyle and disc have moved anteriorly. The disc-condyle relationship remains the same as before clicking. d) Schematic drawing. The dense part of the disc is marked in black.

retrusive condylar paths assigned to the joints with reciprocal clicking (Nos 25, 33, 34, 61) revealed that the posterior part of the retrusive condylar path ran inferior to the protrusive condylar path (Fig. 2). The condylar movement pattern in joint No. 77 was different from the other joints, the protrusive and retrusive condylar paths being congruent.

Disc movement

The radiographic anatomy of a TMJ autopsy specimen as seen in a lateral tomogram using the double-contrast technique in both joint compartments is illustrated in Fig. 4.

In the joints with reciprocal clicking the disc was pushed anterior to the condyle during protrusion. Posterior or inferior to the articular tubercle, the condylar movement retarded. At this stage, the disc, anterior to the condyle, was deformed (Fig. 5 a, b). After a short stationary interval the condyle moved rapidly inferiorly-anteriorly-superiorly and a simultaneous rapid disc movement posteriorly took place (Fig. 5 c, d). These movements were associated with clicking. As a result the condyle was located inferior to the central thin part of the disc and remained so during the rest of protrusion.

During retrusion the condyle was still positioned inferior to the central thin part

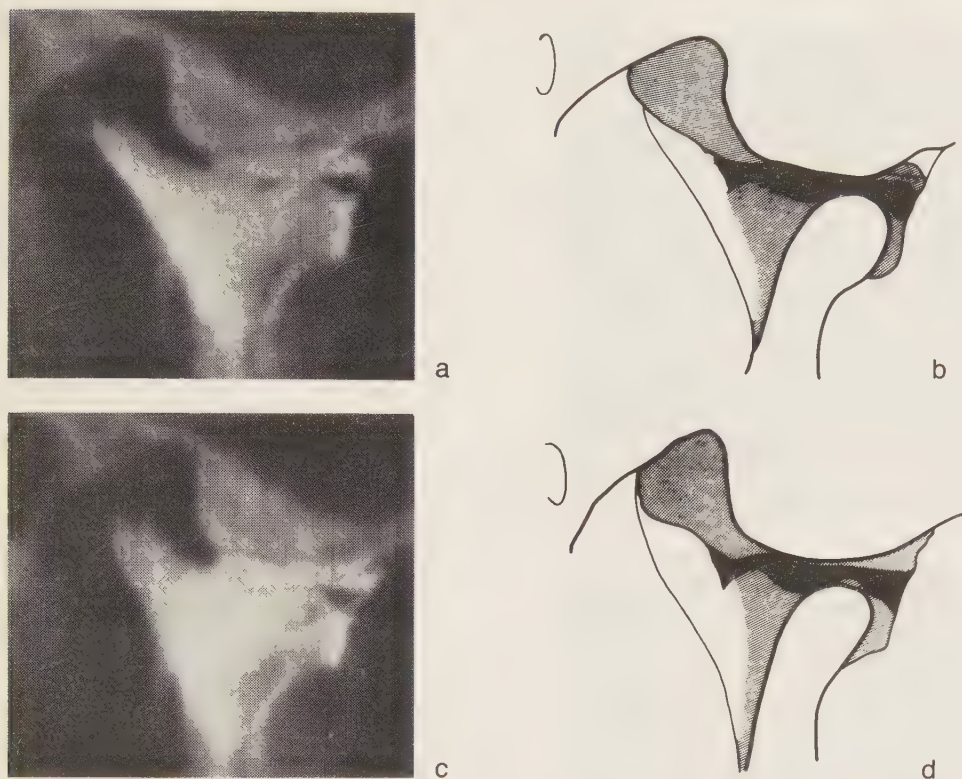
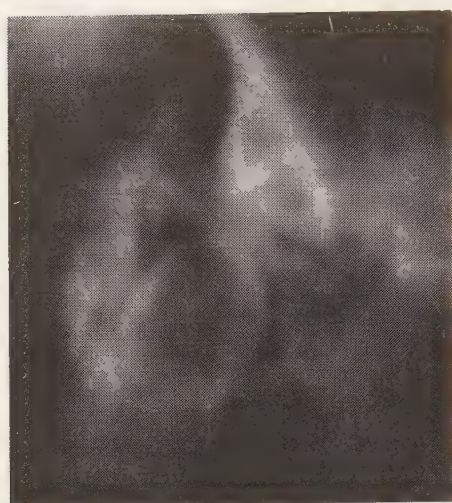


Fig. 8. Cineradiographic frames from a TMJ autopsy specimen with non-reciprocal clicking (No. 77). Contrast media has been injected into the upper and lower compartments. a) Prior to retrusive clicking. The condyle is located inferior to the articular tubercle with the central thin part of the disc in superior position. b) Schematic drawing. The dense part of the disc is marked in black. c) After retrusive clicking. The disc-condyle relationship remains the same as before clicking. d) Schematic drawing. The dense part of the disc is marked in black.

of the disc until the last stage of condylar movement in the fossa (Fig. 6 a, b). A simultaneous rapid movement of disc and condyle associated with clicking then took place. The condyle moved mainly superiorly while the disc moved anteriorly-inferiorly. As a result of these movements, the disc was displaced anterior to the condyle (Fig. 6 c, d). This situation was the initial position for protrusion and a prerequisite for protrusive clicking to occur.

In the fifth joint (No. 77) the movements of disc and condyle were different from those in the other joints. Thus, passing through the bulge of the protrusive and retrusive condylar path, condyle and disc moved synchronously in the same direction (Figs. 7, 8).

Double-contrast tomography was performed before and after clicking during protrusion in one joint (No. 61). Prior to clicking the condyle was located behind the posterior ridge of the disc. In front of the condyle the disc was deformed (Fig. 9 a, b). After clicking the disc was situated more posterior in relation to the condyle and the articular tubercle. The deformation anterior to the condyle was eliminated and the disc appeared straightened (Fig. 9 c, d). In this joint the condyle moved little in association with clicking whereas the disc moved considerably more. The disc movement resulted in a pronounced change in the disc configuration.



a



b



c



d

Fig. 9. Lateral tomogram from a TMJ autopsy specimen with reciprocal clicking (No. 61). Double-contrast technique has been employed in the upper and lower compartments. a) The condyle is located in a position prior to protrusive clicking. Anterior to the condyle the disc is deformed. b) Schematic drawing. The dense part of the disc is marked in black. c) The condyle is located in a position after protrusive clicking. Associated with clicking the disc has moved posteriorly. The deformation anterior to the condyle is eliminated and the disc appears straightened. d) Schematic drawing. The dense part of the disc is marked in black.

Hard tissue changes

Hard tissue changes diagnosed in lateral radiographs and tomograms were present in all five joints. These included thickening of compact bone layer, flattening, erosion and sclerosis (Table 2).

Soft tissue changes

Double-contrast tomography (Fig. 4) was

successful in three joints. It revealed changes within two temporal components and two discs (Table 2). Double-contrast tomography failed in two joints due to momentary leak of injected air through the joint capsule. Therefore, the separation between the joint components was insufficient.

Table 2. *Tissue changes within the TMJ specimens with clicking*

Joint No.	Hard tissue changes registered in radiographs without contrast medium		Soft tissue changes registered in radiographs with contrast medium		
	Temporal component	Mandibular component	Temporal component	Mandibular component	Disc
25	Thickening of compact bone layer within lateral third of fossa.	Flattening of superior condyle outline within central and lateral third of condyle.	Insufficient separation between joint components. No diagnostic information.		
33	5 mm large erosion on posterior slope of articular tubercle within central third.	Thickening of compact bone layer on anterior condyle surface. Erosion within lateral third of condyle.	Thickening of soft tissue layer partly corresponding to erosion on articular tubercle.	*	*
34	*	*	Thickening of soft tissue layer on inferior prominence and posterior slope of articular tubercle.	*	Thin area within lateral-posterior part.
61	*	Flattening of superior outline of condyle partly in central and partly in lateral third.	*	*	Small thin area within most posterior part.
77	Sclerosis in inferior prominence of articular tubercle.	*	Insufficient separation between joint components. No diagnostic information.		

*No changes registered

DISCUSSION

In previous arthrographic studies of TMJs, single contrast technique and single exposures have been used. (1, 6, 8, 9, 10, 13, 14, 16, 20, 24, 26, 32, 43, 44, 46, 47). In combination with cineradiography, however, a double-contrast technique in the upper joint compartment combined with single contrast in the lo-

wer compartment was found to improve the diagnostic possibilities. The slender shape of the lower compartment required a complete filling of radiopaque contrast medium, single contrast, to achieve a definition of the inferior surface of the disc. The upper compartment has a larger volume. Medially as well as laterally there is a recess which reaches inferior to disc

and the lower joint compartment. If totally filled with radiopaque contrast medium it obscures the image of the lower compartment in cineradiography. A double-contrast technique in the upper compartment gave a good definition of the superior surface of the disc without disturbing the image of the lower compartment.

Upon investigations of patients with TMJ clicking, a bulge in the condylar path was observed in association with clicking (23). The same condylar movement pattern was observed in this study and the combination of arthrography and cineradiography made it possible to explain the bulge in the condylar path in association with clicking. In joints with reciprocal clicking, the bulge was caused by the condyle slipping over the posterior ridge of the disc. In the joint with non-reciprocal clicking, coordinated movements of disc and condyle were present. Concerning this joint, it seems reasonable to assume that the bulge in the condylar path could be due to an obstacle probably on the temporal articulating surface.

The observations made in the present study regarding disc and condylar movements associated with clicking were essentially similar to those made by previous authors in patients with TMJ clicking. Thus, the condylar paths from the five investigated TMJ autopsy specimens agreed with those registered in a study on patients using the same equipment and a similar technique (23). They also corresponded with observations made when using an electronic technique to record condylar movement in patients (48).

Superimposition of the protrusive and retrusive condylar paths showed a uniform pattern for the four joints with reciprocal clicking. Consistently, the condylar path within the posterior part of the retrusive movement ran inferiorly to the protrusive condylar path. This was in agreement with observations made in pa-

tients with reciprocal TMJ clicking (12), and can be explained by the disparate condyle-disc relationship during protrusion and retrusion, respectively.

Simultaneous registration of condylar movement and arthrosound confirmed that clicking was associated with a bulge in the condylar path and increased condylar velocity. Corresponding observations have been made on patients using the same equipment and a similar technique (22).

In the joints with reciprocal clicking, the sound was triggered when the condyle slipped over the posterior ridge of the disc. The finding agrees with observations made in previous studies on patients (13, 14, 21, 29, 46). Clicking, however, can occur without incoordinated movements between disc and condyle, as was observed in one joint.

The location of hard and/or soft tissue changes in the temporal joint component correspond to the site of four out of ten bulges in the condylar paths associated with clicking. The location also agreed with the site of structural changes frequently observed in autopsy specimens (5, 18, 25, 33), which has been interpreted as a result of an increased functional load within this part of the joint.

CONCLUSIONS

The results of the present investigation suggested the following conclusions:

- TMJ clicking occurred in autopsy specimens and seemed to be identical to that occurring in patients
- events triggering clicking in autopsy specimens seemed to be similar, if not identical, to those in patients
- a combination of arthrography and cineradiography enabled the study of disc and condylar movements in joints with clicking

- the bulge in the condylar path in four joints was explained by the fact that the condyle slipped over the posterior ridge of the disc in association with clicking and in one joint by the condyle and disc sliding over an obstacle probably on the temporal articulating surface
- it was not possible to determine at what condylar position in the bulge clicking occurred
- it was not possible to identify what actually caused clicking as the movements associated with clicking were rapid, and registered in as little as 0.06
- in order to investigate what actually caused clicking, a highspeed technique must be utilized.

Addendum: After this study was performed the records of the patients of the School of Dentistry in Malmö, Departments of Oral Surgery, ENT and Maxillo Facial Center, General Hospital of Malmö were checked. One of the individuals (No. 25), from whom a clicking joint was removed, had been a patient at the Department of Stomatognathic Physiology, School of Dentistry, Malmö, in 1960, 1967 and 1973. Clinical examinations had revealed bilateral clicking which according to the patients case history had persisted since 1935. Treatment included occlusal adjustments, bite planes and partial dentures. Re-examination in 1974 revealed pain and clicking. The patient died in 1978.

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Paper IV

Movement of disc and condyle in temporomandibular joints with and without clicking

A high-speed cinematographic and dissection study on autopsy specimens

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Isberg-Holm, A. M. & Westesson, P.-L. Movement of disc and condyle in temporomandibular joints with and without clicking. A high-speed cinematographic and dissection study on autopsy specimens. *Acta Odontol. Scand.* 1982, 40, 167-179

High-speed cinematography using 250 frames/s and 500 frames/s was performed on five temporomandibular joint (TMJ) autopsy specimens with clicking, and four without. The joint compartments were visualized by removal of the lateral part of the capsule and disc. In joints without clicking, even and smooth movement of condyle and disc was observed. In joints with clicking the rapid movement of disc and condyle in association with clicking was delineated. In four joints with reciprocal clicking, the clicking was registered at the instant the condyle hit the temporal component after having slipped over the posterior ridge of the disc. In the fifth joint with clicking, movement between condyle and disc was coordinated in association with clicking. At dissection all joints demonstrated deviation in form of both the temporal and mandibular components.

Key-words: Temporomandibular joint function; pathology; autopsy specimens;

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Studies on temporomandibular joints (TMJ) focused on clicking have been mostly concerned with the movement of the joint components (for reviews see 3, 9, 12, 20) but none have provided a satisfactory explanation as to the exact origin of the sound. Cracking in finger joints was investigated by Unsworth, Dowson & Wright (14). In model experiments they observed that when joint surfaces were pulled apart, vapour filled cavities arose due to the creation of a

vacuum. A subsequent collapse of these cavities resulted in cracking. In some joints 20 minutes were required before cracking could recur. Campbell (2) discussed TMJ clicking as a result of the creation of a vacuum, but found it difficult to fit this theory to TMJs.

According to Yavelow & Arnold (20), an abnormal relationship between TMJ components might lead to an obstruction of the normal movement of synovial fluid during function. As a result the fluid

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could be confined under pressure. Normalization of the relationship between the moving parts of the joint would eliminate the abnormal pressure resulting in clicking.

Steinhardt (13) proposed that clicking occurred at the end of the opening movement when the condyle hit the temporal component after having slipped over the anterior ridge of the disc.

Recently, the condylar movement was studied in patients with TMJ clicking (8). The authors found that clicking was associated with increased condylar velocity and an inferiorly directed bulge in the condylar path.

Combining arthrography and cineradiography Isberg-Holm & Westesson (9) investigated five autopsy specimens of TMJs with clicking and could confirm the observation from the previous study on patients (8). In addition, an explanation of the origin of the bulge in the condylar path was offered. Thus, in four joints the bulge was formed by the condyle overcoming the obstacle caused by the posterior ridge of the disc. In the fifth joint the disc and condyle were thought to slip over an obstacle on the temporal articulating surface. Due to the extremely rapid movement of disc and condyle, the cineradiographic technique did not allow scrutiny of this movement. Hence, it was impossible to determine the cause of the clicking.

Prior to the present study it was revealed that the five TMJ autopsy specimens from the previous study (9) proceeded to click during protrusive and retrusive movement in spite of an opening into the joint. This finding was a prerequisite for this study and permitted direct observation into the joint during the entire movements.

High-speed cinematography offers a high degree of resolution in respect of time (cf normal: 24 frames/s, high-speed: exceeding 100 frames/s). High-speed cinematography would permit close exa-

Table 1. Age, sex, number of remaining teeth and presence of dentures in the nine cadavers from which the TMJ specimens were obtained

Subject No.	Age	Sex	Dental status	Presence of TMJ clicking
25*	84	F	7 maxillary teeth 7 mandibular teeth Upper and lower partial dentures	+
33	79	M	Edentulous	+
34	68	F	Upper denture 10 mandibular teeth	+
40	77	M	Upper denture Lower jaw edentulous	÷
61	73	F	Full denture	+
66	72	M	11 maxillary teeth 13 mandibular teeth	÷
77	81	M	Full denture	+
81	81	M	Full denture	÷
84	79	F	Full denture	÷

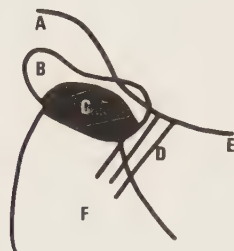
* Exhibited long standing clicking from the removed joint during life time.

mination of the movements associated with clicking.

The present paper reports the results of the application of high-speed cinematography. The aim of the study was – to delineate the movement of disc and condyle in TMJ autopsy specimens with and without clicking – to reveal what actually caused clicking – in addition deviations in form and structure of the joint components were to be studied by dissection.



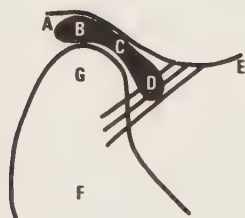
a



b



c



d

Fig. 1 a. High-speed cinematographic frame showing the lateral aspect of a TMJ autopsy specimen without clicking (No. 40). The lateral part of the capsule is removed to visualize the upper joint compartment. Clicking is registered by a microphone connected to a light-diode (arrow) which is activated at clicking.

Fig. 1 b. Schematic drawing explaining anatomical landmarks. A. Articular fossa. B. Upper joint compartment. C. Upper surface of disc covering the condyle. D. Lateral ligament. E. Articular tubercle. F. Neck of the condyle.

Fig. 1 c. To visualize the lower compartment the opening in the capsule is extended and the most lateral part of the disc covering the lateral pole of the condyle is removed. Configuration and position of the disc appear clearly. The most anterior part of the lateral ligament has been preserved. The posterior and anterior ridges of the disc are indicated by arrows.

Fig. 1 d. Schematic drawing explaining anatomical landmarks. A. Articular fossa. B. Posterior ridge of the disc. C. Central thin part of the disc. D. Anterior ridge of the disc. E. Articular tubercle. F. Neck of the condyle. G. Condyle.

MATERIAL

The material included nine TMJ autopsy specimens. Four (Nos 40, 66, 81, 84) were randomly selected from 95 joints without clicking. Five (Nos 25, 33, 34,

61, 77) demonstrated clicking and had previously been investigated by arthrography and cineradiography (9). Four of these (Nos 25, 33, 34, 61) exhibited reciprocal clicking, i.e. clicking during re-

trusion not occurring unless preceded by clicking during protrusion (5). The fifth joint (No. 77) exhibited non-reciprocal clicking. Age, sex, number of remaining teeth and the presence of dentures at autopsy are presented in Table 1.

METHODS

High-speed cinematographic equipment

A high-speed cine-camera, Locam, for 16 mm film was used to register movement of the condyle and disc during protrusion and retrusion including the rapid movement associated with clicking. The camera had intermittent film feed with a framing speed adjustable up to 500 frames/s. To check the framing frequency, timing lamps were exposed on all films with a constant interval of 0.1 s. At framing frequencies of, 250 and 500 frames/s the variation was less than ± 3 per cent. The camera shutter was adjusted for 120° which gave an exposure time of 1/750 s at a speed of 250 frames/s and 1/1500 s at 500 frames/s. A depicted area of approximately 35 mm x 50 mm was obtained utilizing a Switar 25 mm f:1.4 lens and a 5 mm shim. An aperture of 11 and Eastman Colour-negative Tungsten 7247 film were used. The films were developed and copied.

During high-speed cinematography the TMJ specimen was placed in a positioning device (15). The device and the camera were fixed to two separate immobilized stands to avoid vibration transmission between camera and joint specimen.

All nine TMJ autopsy specimens were provided with an opening in the lateral part of the joint capsule in order to visualize the upper joint compartment (Fig. 1 a, b).

Cinematography using 250 frames/s was performed on all nine joints in order to study the movement of disc and con-

dyle during protrusion and retrusion. To delineate the rapid movement associated with clicking, 500 frames/s were used at iterated registrations. The high-speed cinematography was performed from a lateral view.

After initial registration during protrusion and retrusion, the opening in the capsule was extended in the five joints with clicking and in two of the non-clicking joints (Fig. 1 c, d). Tissue of the lateral part of the joint capsule was removed as was the most lateral part of the disc covering the lateral pole of the condyle in order to visualize both the lower and the upper joint compartments. A new session of high-speed cinematography was then performed. The purpose of this step by step recording was to study whether the more extended opening into the joint and the removal of the lateral part of the disc influenced the movement pattern of the joint. The removed tissue was inspected macroscopically and pathological changes were registered.

In one joint without clicking (No. 40), the main part of the lateral ligament was preserved during the initial cinematography. The ligament was then removed and the movements recorded once more during protrusion and retrusion. The purpose was to study the influence on the disc and condylar movements following removal of the lateral ligament.

In one joint (No. 77) a metal stud, diameter 2 mm, was driven laterally into the compact bone of the neck of the condyle. The stud served as a reference point for analyzing the movement of the mandibular joint component.

Sound recording

Sound recording direct on the film is not used in high-speed cinematography. Framing frequencies are different during recording and analysis causing sound distortion. For this reason, clicking was registered using another method. A con-

tact microphone, Elema-Schönander EMT 25, was fixed to the squama temporalis and connected to a specially constructed signal amplifier which fed a light-diode. The light-diode was placed on the specimen within the depicted area. Clicking was indicated by a red light and recorded on the film (Fig. 1).

Signal amplifier

The signal amplifier was constructed in three amplifier stages ($3 \times \mu\text{A } 741$) with simple filters to suppress low frequencies. A monostable rocker was triggered from the amplifier outlet. The rocker fed a light-diode via a power stage. Duration of the light impulse at signal was about 50 ms.

Another monostable rocker blocked further indication for 0.5 s after a signal pulse. The current through the light-diode was 500 mA at signal. The signal level from the microphone was 0.1 mV to give output signal to the light-diode. The delay in the amplifier was $10 \mu\text{s}$ and in the amplifier and microphone together $100 \mu\text{s}$.

Analyses

The film copies were qualitatively analyzed at a Steinbeck film cutting table, St 400 W. Movement of disc and condyle was studied at varying film speeds from stills to 75 frames/s. The rapid movement in association with clicking was analyzed frame by frame with reference to time.

Illustrations from the film were chosen strictly by the principle of a constant number of frames between each illustration. The total number of frames depicting a protrusion and retrusion, respectively, were divided to obtain a suitable number of illustrations with equal intervals. In joints with clicking, the sequence of illustrations were chosen to show the frame when the light-diode lit at clicking. The selected frames from the negative

colour film were reproduced onto black and white film which was developed in a reversal developer. Paper prints were made.

Dissection

Dissection of all nine joints followed the high-speed cinematography. By a circumferential incision in the capsule, the disc and condyle were separated from the temporal component. The disc was removed from the condyle. The appearance of the temporal component, disc and condyle was recorded and colour photographed. The articulating surfaces were examined macroscopically. The presence of osteoarthritis and form deviation were judged according to the principles applied by Carlsson & Öberg (3). After dissection, the joints were fixed in 10% neutral formalin.

The observations at the dissection of the joints with clicking were compared with the radiographic findings of these joints obtained in a previous study (9).

RESULTS

Influence of tissue removal

The occurrence of clicking was not influenced by the removal of the lateral part of the capsule and the most lateral part of the disc covering the lateral pole of the condyle. Clicking in relation to the condylar path was not affected in the joint with non-reciprocal clicking (No. 77). In the joints with reciprocal clicking (Nos 25, 33, 34, 61) the retrusive clicking was not affected. During protrusion however, the condyle could be moved somewhat more anteriorly along the articular tubercle before clicking occurred.

The removal of the lateral ligament was not seen to influence the movement of disc and condyle.



Fig. 2 a. Serial high-speed cinematographic frames (250 frames/s) of a TMJ autopsy specimen without clicking (No. 40). The movement and configuration of the disc appear clearly. The serial demonstrates the movement of disc and condyle during protrusion (frames 0–640) and retrusion (frames 800–1440). At the beginning of protrusion the condyle was located in the fossa inferior to the transition between the posterior ridge and the central thin part of the disc (frame 0). During protrusion the condyle rotated smoothly against the inferior surface of the disc. At the same time a translation of the disc and condyle took place anteriorly along the articular tubercle. During retrusion the movement was reversed. The condylar paths during protrusion and retrusion were even.

Fig. 2 b. Schematic drawings.

Joints without clicking

In the joints without clicking (Nos 40, 66, 81, 84) movement of the disc and condyle was synchronized during protrusion and retrusion (Fig. 2). In the fossa, the con-

dyle was placed inferior to the posterior ridge of the disc. During protrusion the condyle rotated smoothly against the disc. At the end of protrusion the condyle was located inferior to the transition between the central thin part of the disc and



Fig. 3. High-speed cinematographic frames showing a TMJ autopsy specimen (No. 61) with reciprocal clicking. Reciprocal clicking was referred to as clicking during retrusion not occurring unless preceded by clicking during protrusion. In some of the illustrations the lateral part of the disc (arrow frame 180) is hanging over the lateral pole of the condyle obscuring the posterior ridge of the disc. In the original colour film, the posterior ridge was clearly identified, due to movement.

Fig. 3 a. Serial high-speed cinematographic frames (500 frames/s) demonstrating the movement of disc and condyle during protrusion. The disc was pushed anterior to the condyle and no smooth rotation took place. The protrusion terminated with clicking (frame 420).

Fig. 3 b. Schematic drawings.

Fig. 3 c. Serial high-speed cinematographic frames (250 frames/s) demonstrating the movement of disc and condyle during retrusion. At beginning of retrusion the condyle was located inferior to the central thin part of the disc and no smooth rotation took place. The retrusion terminated with clicking (frame 88).

Fig. 3 d. Schematic drawings.

its anterior ridge. The posterior attachment of the disc appeared to be stretched.

During retrusion the movement was reversed.

Joints with reciprocal clicking

Movements of the disc and condyle during protrusion and retrusion in a joint with reciprocal clicking are illustrated in Fig. 3. The movements were in agreement with the results of a previous arthrographic and cineradiographic study of the same joints. (9). Therefore, only the rapid movements associated with clicking during protrusion and retrusion will be described. These rapid movements commenced after an interval of condylar retardation, which appeared independently of the velocity of the preceding condylar movement. A frame by frame analysis revealed that the movements could be divided into two subsections both during protrusion and retrusion.

During protrusion the rapid movement associated with clicking occurred when the condyle was located inferior to the articular tubercle.

Subsection 1 during protrusion:

From a position behind the posterior ridge of the disc the condyle moved rapidly inferiorly and anteriorly underneath the posterior ridge. The disc was motionless (Fig. 4, frame 412).

Subsection 2 during protrusion:

The condyle, now in a position inferior to the posterior ridge, no longer exerted any pressure on the disc in an anterior direction. The disc moved posteriorly over the condyle. The condyle moved rapidly superiorly and hit the temporal component with the central thin part of the disc in between. Thus the normal relationship between disc and condyle was restored. The light-diode indicated clicking at the instant the condyle hit the temporal component (Fig. 4, frame 420).

During the major part of retrusion, the disc and condyle maintained their normal relationship. At the end of retrusion, following an interval of condylar retardation, the rapid movement associated with retrusive clicking commenced.

Subsection 1 during retrusion:

From a normal position inferior to the



Fig. 4 a. Serial high-speed cinematographic frames (500 frames/s) showing the same TMJ (No. 61) as in Figure 3, now restricted to the rapid movements associated with protrusive clicking. In frame 404 the rapid anterior movement of the condyle has just commenced. In frame 412 the condyle is about to slip over the posterior ridge of the disc. In frame 420 the disc, no longer pressed anteriorly by the condyle, has rapidly moved posteriorly. Clicking occurred at the instant the condyle hit the temporal component. After clicking the condyle was normally situated inferior to the central thin part of the disc.

Fig. 4 b. Schematic drawings.

central thin part of the disc (Fig. 5, frame 80) the condyle moved rapidly inferiorly-posteriorly underneath the posterior ridge of the motionless disc.

Subsection 2 during retrusion:

The disc, no longer pressed posteriorly by the condyle, moved rapidly anteriorly along the articular tubercle. The condyle moved rapidly superiorly to the space now falling vacant and hit the temporal component with only the posterior loose part of the disc in between. The light-diode indicated clicking at the instant the condyle hit the temporal component (Fig. 5, frame 88). As a result of the movement associated with clicking during retrusion,



Fig. 5 a. Serial high-speed cinematographic frames (500 frames/s) showing the same TMJ (No. 61) as in Figures 3 and 4, now restricted to the movements associated with retrusive clicking. In frame 72 the condyle was located inferior to the central thin part of the disc and its rapid movement backward had commenced. In frame 88 the condyle has slipped posteriorly over the posterior ridge of the disc. Simultaneously the disc has moved anteriorly. Clicking was released at the instant the condyle hit the temporal component (frame 88). As a result of movements associated with clicking the disc was displaced anterior to the condyle and remained so until the normal disc-condyle relationship was restored in association with a following clicking during protrusion.

Fig. 5 b. Schematic drawings.

the disc was displaced anteriorly and remained so until the normal disc-condyle relationship was restored in association with a following clicking during protrusion. The retrusive clicking was a prerequisite for clicking during protrusion to occur.

The frame by frame analysis revealed that subsection 1 during protrusion lasted 0.012 s – 0.036 s and during retrusion 0.006 s – 0.008 s. Subsection 2 had a duration of approximately 0.002 s during both protrusion and retrusion.

Joint with non-reciprocal clicking

The high-speed cinematographic films confirmed the findings of the previous study regarding movement of the disc (9), (Fig. 6). In addition it was revealed that the condyle was invariably placed inferior to the central thin part of the disc and no smooth condylar rotation against the inferior surface of the disc took place during protrusion and retrusion. In connection with clicking, movement of the condyle and disc was still synchronized.

Frame by frame analysis revealed that when the condyle had reached a position inferior to the articular tubercle, the disc and condyle jumped approximately 1 mm along the articular tubercle and clicking was indicated by the light-diode. In association with retrusive clicking, the condyle and disc jumped approximately 0.5 mm posteriorly along the articular tubercle with unchanged mutual relationships. Movement in association with non-reciprocal clicking was fast and was depicted in two cineframes only.

Dissection

Macroscopic observations at dissection of all nine joints are presented in Table 2. All examined joints exhibited deviation in form of both the temporal and mandibular joint component, mainly demonstrated by flattening (Fig. 7). In five joints (Nos 25, 33, 61, 77, 81) the discs exhibited a mediolateral ridgelike thickening on the inferior surface under the normal posterior ridge.

In joints with reciprocal clicking (Nos 25, 33, 61) the condyle was seen to slide behind the mediolateral thickening at the end of retrusion. In the joint without clicking (No. 81) and in the joint with non-reciprocal clicking (No. 77) the condyle could not even be forced behind the thickening.

In three of the four joints with reciprocal clicking (Nos 25, 33, 34) the posterior



Fig. 6 a. Serial high-speed cinematographic frames (500 frames/s) of a TMJ autopsy specimen (No. 77) with non-reciprocal clicking. At the beginning of protrusion the condyle was located inferior to the central thin part of the disc (frame 0). During protrusion the condyle was invariably located in this relation to the disc. When the condyle and disc were located inferior to the articular tubercle they rapidly jumped anteriorly along it and clicking occurred (frame 40). In connection with clicking, movement of the condyle and disc was still synchronized. During retrusion a reversed course of movements was observed.

Fig. 6 b. Schematic drawings.

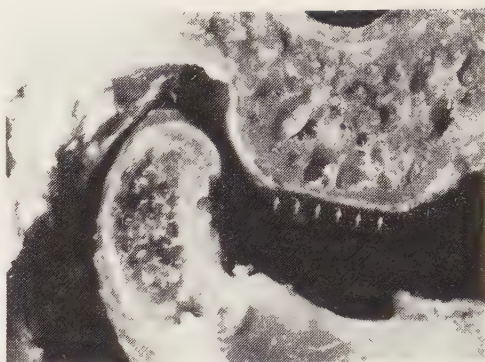


Fig. 7. Cross section of lateral part of TMJ autopsy specimen with clicking (No. 77). The joint capsule and disc are removed. The most lateral part of the condyle and the articular tubercle are removed by saw. The inferior prominence of the articular tubercle demonstrates a marked flattening (arrows). The fossa is narrow in anterior-posterior direction. The posterior slope of the articular tubercle is steep. The compact bone layer of the condyle is thickened anteriorly and superiorly.



Fig. 8. Anterior aspect of the condyle from a right TMJ specimen with clicking (No. 77). The condyle exhibits a small spicule (arrow) on the medial part of the superior surface. The spicule fitted into a depression of the same size on the inferior surface of the disc which prevented the normal rotation of the condyle against the inferior surface of the disc.

surface of the condyle appeared flat and almost concave.

In joint 77 a spicule was observed on the superior surface of the condyle (Fig. 8). The spicule fitted into a depression on the inferior surface of the disc, preventing the disc from moving in relation to the condyle. No joint demonstrated osteoarthritis.

Table 2. *Pathological findings and deviation in form of TMJ autopsy specimens with and without clicking. Macroscopic observations at dissection*

Joint No.	Clicking	Temporal component	Mandibular component	Disc
40	no clicking	Flattening of articular tubercle and a 3 mm depression laterally.	Small flattening of lateral part.	No findings.
66	no clicking	Uneven surface and flattening of lateral $\frac{1}{3}$ of articular tubercle.	Small elevation on lateral pole of condyle.	Tight attachment between disc and poles of condyle.
81	no clicking	Flattening of articular tubercle.	Uneven surface of lateral part.	Mediolateral ridgelike thickening on inferior surface inferior to normal posterior ridge.
84	no clicking	Flattening of lateral $\frac{2}{3}$ of articular tubercle. Uneven surface most laterally.	Small flattening of superior surface. Small elevation laterally.	No findings.
25	reciprocal clicking	Flattening of lateral $\frac{1}{3}$ of articular tubercle.	Flattening, almost concavity, of posterior surface, most pronounced medially.	Mediolateral ridgelike thickening on inferior surface inferior to normal posterior ridge. Flattening of anterior $\frac{2}{3}$.
33	reciprocal clicking	Flattening of lateral $\frac{2}{3}$ of articular tubercle.	Flattening, almost concavity, of posterior surface, most pronounced medially.	Mediolateral ridgelike thickening on inferior surface inferior to normal posterior ridge. Impression by condyle posterior to thickening.
34	reciprocal clicking	Small elevation on lateral part of articular tubercle.	Flattening, almost concavity, of posterior surface in the lateral $\frac{1}{3}$. Small depression on superior surface.	No findings.
61	reciprocal clicking	Flattening of inferior prominence of articular tubercle. Elevation on lateral part of articular tubercle. Steep posterior slope of articular tubercle.	Mediolateral ridge of small elevations on superior surface. 5 mm x 5 mm elevation on lateral pole of the condyle.	Mediolateral ridgelike thickening on inferior surface inferior to normal posterior ridge. Thinning over lateral pole.
77	non-reciprocal clicking	Flattening of inferior prominence of articular tubercle. Anterior extension of articulating surface. Narrow fossa in anterior-posterior direction. Steep posterior slope of articular tubercle.	1 mm large spicule on superior surface fitting into a depression of same size on inferior surface of disc.	Mediolateral ridgelike thickening on inferior surface inferior to normal posterior ridge. Thinning of lateral $\frac{1}{3}$. 1 mm depression on inferior surface of central thin part.

Dissection findings compared to radiographic observations

At dissection a flattening was seen on the articulating surface of the tubercle of joint 33. In a previous study (9) an erosion of the bone was radiographically observed in this area.

In joint 77 sclerosis was found in the inferior prominence of the articular tubercle. At dissection a flattening of the articulating surfaces was observed in this area (Fig. 7). No further findings were made at dissection in areas which radiographically demonstrated changes.

DISCUSSION

The following findings in the previous arthrographic and cineradiographic study (9) indicate that the mechanism of reciprocal clicking in the autopsy specimens was the same as in patients:

- clicking sounded the same
- the posterior part of the closing condylar path ran inferior to the opening condylar path as found in patients by Farrar (5)
- clicking was associated with a bulge in the condylar path as found in patients by Isberg-Holm & Ivarsson (8) and Willigen (19)
- the condyle – disc relationship in association with clicking was the same in autopsy specimens as found in patients during arthrography (1, 4, 7, 10, 16, 17) and at surgery (11, 18).

It is unlikely that clicking in the autopsy specimens was a postmortem artifact as the condyle in the other 95 joints could not be moved, manipulated or forced so as to release clicking. Furthermore, for one of the individuals, from whom a clicking joint was obtained, the case history revealed long standing clicking of the affected joint during the life time of the patient.

High-speed cinematography performed on TMJ autopsy specimens without clicking demonstrated synchronized and smooth movements of the disc and condyle during protrusion and retrusion. This was in agreement with arthrographic observations in individuals with TMJs characterized as normal (1, 4, 6, 7, 10, 16, 17).

Previous studies on autopsy specimens (9) as well as on patients (8, 19) have demonstrated an irregularity or bulge in the condylar path associated with clicking. In the four joints with reciprocal clicking the high-speed cinematography demonstrated that the clicking was released after the condyle had slipped over the posterior ridge of the disc. Also, it could be shown that the sound was produced at the instant the condyle and disc hit the temporal component, which likely corresponds to the end of the bulge.

In the fifth joint demonstrating non-reciprocal clicking and coordinated movement of the disc and condyle, the origin of the clicking could not be fully disclosed. Despite the high-speed cinematography it was not possible to separate the cause of events leading to clicking. Clicking occurred in connection with a jump by the disc and condyle but these could not be seen to actually hit the tubercle. It is still probable that clicking was released by the disc and condyle hitting the temporal component. It is also probable that the rather extensive deviation in form found at dissection could form an obstacle that the disc and condyle had to overcome. Observation from this fifth joint indicates that events other than dislocation can lead to clicking.

This study on autopsy specimens has shown that clicking in TMJs is caused by the condyle and disc hitting the temporal component. It seems reasonable to assume that the same sequence of events occurs in patients.

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Paper V

DOUBLE-CONTRAST ARTHROTOMOGRAPHY OF THE TEMPORO-
MANDIBULAR JOINT. Introduction of an arthrographic
technique for visualization of the disc and articular
surfaces.

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ABSTRACT

A technique for double-contrast arthrotomography of the temporomandibular joint was developed. Iodine-contrast medium and air were injected into both joint compartments. Lateral tomography followed using a multi-film cassette.

Double-contrast arthrotomography was applied to 105 patients and depicted with good definition the configuration and position of the disc, its attachments and the articular surfaces. Normally the disc was biconcave with its posterior band lying superior to the condyle. Anterior displacement of the disc was characterized by the posterior band lying anterior to the condyle. In addition to displacement the disc could also be perforated and/or deformed taking on a biconvex shape. Postarthrographically the patients experienced transient discomfort but there were no serious complications.

Double-contrast arthrotomography seems to facilitate the diagnosis of internal derangement by an improved radiographic image of the intra-articular anatomy.

INTRODUCTION

Temporomandibular arthrography has shown to be a reliable method for diagnosis of internal joint derangement (1-10). Single-contrast arthrography has been the common method and refers to the filling of the joint compartments with a radiopaque contrast medium before radiography. The single-contrast technique is usually combined with tomography improving the radiographic representation of the joint (4, 5, 7, 8, 11, 12).

In double-contrast arthrography the articular surfaces are coated by radiopaque contrast and the joint compartment expanded by air. Double-contrast arthrography has been widely applied to other joints (13-16) whereas only attempts have been made to use this technique for the temporomandibular joint (TMJ) (17). The information from double-contrast arthrography of the knee (18, 19) and shoulder (15) has been considered to be superior to that resulting from single-contrast arthrography. It is reasonable to assume that double-contrast arthrography of the TMJ is superior to single-contrast arthrography. Recent methods for conservative and surgical treatment of TMJ disorders (4, 5, 6, 8, 20) are based on accurate information of the soft tissue of the joint and have increased the use of TMJ arthrography.

For these reasons a technique for TMJ double-contrast arthrotomography was developed and applied to autopsy specimens (21). The resulting arthrotomograms depicted the disc and the articular surfaces with good definition. The results of the autopsy study encouraged me to apply double-contrast arthrotomography of the TMJ to patients. This paper describes the technique as modified for clinical use and the arthrographic findings are reviewed.

PATIENTS AND METHODS

The arthrographic technique was gradually modified during 123 examinations of 105 patients in which clinical examination indicated TMJ internal derangement. There were 79 females (twelve with bilateral and two with repeated examinations) and 26 males (four with bilateral examinations) with a mean age of 33 years (range 12-75).

Before arthrography, TMJ radiography was carried out according to a standard procedure in our department (22). This included a submentovertex projection (23), individualized lateral oblique transcranial projection (24) and transmaxillary projection (25).

Lateral tomography was performed at intercuspal position (closed mouth) immediately prior to arthrography. The patient was in a seated position with the head immobilized in a cephalostat, modified after Iikubo, Korsell and Omnell (26).

The cephalostat could be rotated about the vertical axis so that the horizontal condylar axis of the examined joint was parallel to the central X-ray beam (24).

A Philips Universal polytome (X-ray tube Siemens Bi 150/30/50 R, focal spot 0.6 mm x 0.6 mm) and hypocycloidal movement were used. Simultaneous tomography was employed using a cassette with five pairs of intensifying screens (Siemens Simultan Verstärkerfolien) and five films (Ilford Rapid R) with an interspace of 3 mm. Exposure data were 73 kV, 107-133 mA and 6 s. The diameter of the cross-section of the beam in the tomographic plane was 42 mm. No grid was used. According to the resulting tomograms corrections were made of the position of the patient, level of sectioning and exposure data. The individual anatomy of the joint was studied to facilitate the placement of the cannulas.

Arthrography

The patient was transferred to a fluoroscopic unit and placed in a supine position. The head was positioned on the image intensifier (Siemens Sirecon compact) and turned about 80° towards the side not being examined. The superiorly placed X-ray tube (Siemens Bi 125/12/50 R, focal spot 0.3 mm x 0.3 mm) was tilted $5-10^{\circ}$ caudally against the vertical plane. In this way a lateral

oblique transcranial projection of the TMJ was obtained. The projection was controlled by fluoroscopy and adjusted to achieve optimal image of the joint.

Local anesthesia was obtained by infiltration of about 0.8 ml Xylocain-Adrenalin 2 per cent* (lidocain HCL 2% with epinephrine 1:80 000) into the tissue posterior to the condyle and 0.5 ml inferior to the articular tubercle.

The lower compartment was cannulated first by inserting a cannula** (1.1 mm x 32 mm) posterior to the condyle. With the patient's mouth in closed position the cannula was directed against the posterior surface of the condyle and when bone contact was reached the position was fluoroscopically checked. The patient was then asked to open his mouth slowly. If correctly positioned, the condylar movement could be felt with the cannula. Fluoroscopically the needle tip remained juxtaposed to the condyle during movements. The inner needle was withdrawn and the catheter medially advanced into the posterior recess of the lower compartment.

The upper joint compartment was cannulated while the patient's mouth was in closed position. The bevel of the cannula** (0.8 mm x 25 mm) was oriented superoanteriorly. The cannula was inserted about 10 mm anterior to the cannula used for the lower compartment and directed against the posterior slope of the articular tubercle. As bone contact was obtained the position was fluoroscopically checked. If correctly positioned the inner needle was withdrawn and the catheter medially advanced into the upper compartment. Generally, it could be sensed in both compartments when the needle passed the capsule and slipped into the joint.

* Astra Pharm. Production, S-151 85 Södertälje, Sweden

** Angiocath, The Desert Company, Sandy, Utah 84070,

After placement of both catheters about 0.2 ml and 0.3 ml Amipaque*** (metrizamid 300 mg I/ml) were injected into the lower and upper compartments, respectively, via extension tubes and under fluoroscopic observation. After injection into the lower compartment a single exposure was made to document the location of the contrast medium. Injections of contrast medium were the final check of catheter positions. After successful cannulation, the contrast medium in the lower compartment should flow freely around the condyle and in the upper compartment along the articular tubercle. During injection, the contrast medium should enter the joint without any resistance. With some experience it was possible to detect a faulty position by the resistance to injection. Movements of disc and condyle were studied fluoroscopically.

The tips of the catheters were left in the joint compartments and the outer parts of the catheters fixed to the skin with tape. The patient was transferred to the tomographic unit and seated with the head immobilized in the cephalostat in the original position. With the mouth of the patient at maximum opening another 0.3 ml and 0.5 ml of Amipaque were injected into the lower and upper compartments, respectively, and followed by tomography. When closing the mouth the contrast medium was allowed to reflux in order to avoid overexpansion and rupture of the compartments. Arthrotomography was then performed at the intercuspal position.

With the aid of catheters in the joint compartments most of the iodine contrast medium was aspirated. Using glass syringes with low friction and another pair of extension tubes air was injected into both compartments simultaneously until an elastic resistance was experienced. Double-contrast tomograms were obtained at

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maximum mouth opening and at intercuspal position. In addition, clicking joints were examined at condylar positions prior to and after clicking. The amount of air injected varied for different condylar positions and different joints, with an approximate range of 0.2 - 0.6 ml and 0.1 - 0.4 ml for the upper and lower compartments, respectively. When obtaining double-contrast tomograms, the air injected was carefully compressed and the extension tubes closed by forceps. The air was allowed to move freely in and out of the syringes during condylar movement.

Following arthrography most of the injected air was aspirated. One week after each examination a secretary had a structured telephone interview with the patient concerning postarthrographic discomfort.

RESULTS

Both compartments were cannulated in 112 examinations. In nine examinations only the lower compartment was cannulated and in two examinations only the upper compartment. In five examinations neither upper nor lower compartment could be cannulated at the first attempt. Three of these joints were examined on a second occasion with successful cannulation of both compartments. Arthrography was not repeated on the remaining two joints.

The configuration and position of the disc, its attachment to the capsule anteriorly and posteriorly and the configuration of the joint compartments appeared clearly on the double-contrast arthrotomograms. The best depiction of the disc and articular surfaces was obtained from the central part of the joint. Occasionally disc configuration was obscured on arthrotomograms obtained at intercuspal position due to the narrowness of the joint

compartments between the condyle and the fossa. This was overcome by obtaining tomograms at slightly opened mouth which usually disclosed the disc configuration more clearly (Fig. 1 A). The most distinct arthrograms were obtained immediately after injection of the contrast media. A gradual diffusion of the iodine contrast medium occurred, although it was still possible to obtain double-contrast arthrograms adequate for diagnostic purposes ten minutes after the initial injection. The optimal amount of injected air for the upper and lower compartments varied for different condylar positions and different joints. At intercuspal position only a small amount of air could be injected (Fig. 1 A), whereas considerably more could be introduced at maximum opening (Fig. 1 B).

Twenty-seven examinations revealed radiographically normal TMJs, characterized by the disc being biconcave and at intercuspal position located with the posterior band (i.e. posterior thick part) superior to the condyle (Fig. 1 A). During the opening movement the condyle moved along the inferior surface of the disc and was located inferoanteriorly to the posterior band of the disc at maximum opening (Fig. 1 B).

Forty-one TMJs exhibited anterior disc displacement with reduction (i.e. repositioning of the disc to normal on opening) (Fig. 2). This was characterized by the posterior band at intercuspal position lying anteriorly to the condyle and elongation of the posterior disc attachment (i.e. bilaminar zone) (Fig. 2 A). During mouth opening, clicking or hesitation was registered. This was associated with changed disc position from anterior displacement to normal superior position (i.e. reduction). Once clicking or hesitation occurred, the condyle was capable of completing the translation beyond the crest of the articular tubercle. At maximum opening the disc was normally located with its posterior band posterosuperior to the condyle (Fig. 2 C). During

the following closing sequence another usually more discreet clicking or hesitation was registered and the disc was again anteriorly displaced.

Twenty-nine of 41 TMJs with anterior disc displacement with reduction exhibited an oblique disc position, i.e. anterior displacement laterally while the position medially remained normal (cf Figs 2 A, 2 B). In twelve TMJs the disc was anteriorly displaced laterally as well as medially. In two patients with anterior disc displacement with reduction, the condyle was displaced anteriorly to the anterior band of the disc at maximum opening. During the following closing movement the condyle remained anterior to the anterior band of the disc causing folding of the disc and a locked open position. The disc configuration among the 41 TMJs with anterior disc displacement with reduction varied from normal biconcave to biconcave with marked enlargement of the posterior band and diminishing of the central thin part and anterior band.

Forty-eight examinations revealed TMJs with anterior disc displacement without reduction (i.e. without repositioning of the disc to normal on opening) (Figs 3, 4, 5). This was characterized by the posterior band of the disc lying anteriorly to the condyle both at intercuspal position (Fig. 3 A) and at maximum opening (Fig. 3 B). Thus, the disc acted as a block to the anterior translation of the condyle. The posterior disc attachment was elongated. The dense part of the disc was deviated in form, varying from slight enlargement of the posterior band of a biconcave disc (Fig. 3 A) to a totally biconvex disc (Fig. 4). In eleven of the TMJs with anterior disc displacement without reduction perforation was fluoroscopically diagnosed by simultaneous opacification of the upper compartment during injection of contrast medium into the lower compartment, (Fig. 5 A). Additionally, two of the perforations were definitely demonstrated on double-contrast arthro-

tomograms (Fig. 5 C). These were found in the posterior part of the disc and were best seen on arthrograms obtained at maximum opening. The anteroposterior dimension of the perforation could be measured and with the aid of the multi-film cassette the mediolateral location and approximate size could also be estimated. In all but three TMJs with perforation, the disc was found to be of even thickness or biconvex in addition to the elongation of the posterior attachment.

One patient exhibited symmetric changes bilaterally including thinning, elongation, surface irregularities of the disc, flattening and erosion of condyle and temporal component, all of which signify granulomatous arthritis. Three TMJs from different patients demonstrated extensive perforation indicating extensive osteoarthritis. In spite of a rather high injection pressure only small amounts of contrast media could be injected into two TMJs of different patients with limitation of mouth opening. Double-contrast arthrography demonstrated adhesions between the condyle and the inferior surface of the disc.

Following 57 examinations postarthrographic discomfort occurred during the day of examination. In 66 examinations the discomfort generally remained for one to two days with a range of 1 to 8 days. Postarthrographic discomfort included tenderness (33 examinations), pain (16 examinations), trismus (10 examinations) and headache (7 examinations). Nineteen patients took a mild analgesic to overcome pain or headache. Thirteen patients reported some sleeping difficulties during the night following the examination. One patient developed a hematoma in the joint region. There were no serious complications.

DISCUSSION

Earlier, a technique for double-contrast tomography was applied to TMJ autopsy specimens (21). When this technique was used on patients, technical improvements were gradually introduced. As a result, a procedure evolved which could be easily applied with little discomfort for the patients. Double-contrast arthro-tomography of the TMJ enables a clear demonstration of the position and configuration of the disc with its anterior and posterior attachments. Furthermore, the articular surfaces and thereby the outline of the joint compartments are depicted in an informative way.

The technique for double-contrast arthrotomography of the TMJ was modified in three ways compared to that described for TMJ autopsy specimens (21). First, the iodine contrast medium Conray (iothalamate sodium 400 mg I/ml) was replaced by Amipaque (metrizamid 300 mg I/ml) which has a lower neurotoxicity (27). The bony wall between the fossa and the subarachnoidal space can be paper thin (28) and in the presence of an accidental perforation or fistula (Wilkes, C.H., unpublished observation) Amipaque would cause less harm. This contrast medium is also advantageous in permitting prolonged time for radiography (29). This characteristic of Amipaque was of value for TMJ arthro-graphy as a number of radiographs were obtained at different condylar positions. Second, the veinpoint needles were replaced by cannulas, a method also employed by previous authors (5, 6, 7). The cannulas permitted adjustment of the amount of injected contrast media. Third, the sequence of injections was changed. The 0.5 ml of air initially injected in autopsy specimens was replaced by iodine contrast medium enabling fluoroscopic control of the position of the catheter.

It is beyond the scope of this paper to systematically compare the information yielded by single or double-

contrast arthrography. Judging from my clinical experience and published single-contrast arthrograms, however, the double-contrast technique offers an improved radiographic representation of the intra-articular anatomy. In single-contrast arthrography the entire joint compartments are filled with highly radiopaque contrast medium. Under these circumstances contrast material located outside the tomographic plane will give rise to a radiopaque pseudoimage. This impairs the radiographic representation of the anatomical structures and the contrast medium located in the tomographic plane proper as principally pointed out in previous studies (30, 31). Since in double-contrast arthrography air constitutes the major portion of the contrast material this undesirable effect is strongly avoided.

According to Eckerdal (30) who analysed the information provided by tomography of the mineralized parts of the TMJ, the central two thirds of the joint region are clearly reproduced under favourable circumstances. Similar findings were made in this study concerning the depiction of the disc and articular surfaces. Thus, the central part was more accessible for diagnosis by lateral double-contrast arthrotomography than the most lateral and most medial parts of the joint. As anterior disc displacement with reduction was found in this study to be frequently associated with oblique disc position, depiction of the lateral part of the joint is essential for the diagnosis. Therefore, double-contrast arthrotomography was preceded by transcranial arthrography depicting the lateral part of the joint. The two techniques are complementary in order to avoid false negative findings. The lack of this radiographic combination may be an explanation as to why the oblique disc position, already identified anatomically in 1918 (32), has not until recently been recognized in arthrographic studies (8). The different appearance of configuration and position of the disc at different depths is in accordance with observations made by Omnell and Petersson

(24) who performed serial tomography of the TMJ and showed the radiolucent space between the condyle and fossa to differ in width from the lateral to the medial portion of the joints. This was also shown when employing axial tomography of the TMJ (33). All these results emphasize the importance of serial examination throughout the mediolateral dimension of the joint.

During one complete unilateral examination with this arthrographic technique, the absorbed dose to the eye and thyroid gland was approximately 0.6 mGy and 0.8 mGy, respectively, (34).

Double-contrast arthrotomography demonstrates clearly the intra-articular anatomy of the TMJ and produces useful information for treatment planning. The arthrographic diagnosis is essential when considering the desirability of surgical intervention for repair or excision of the disc when conservative treatment has failed.

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LEGENDS

- Fig. 1. Lateral double-contrast arthrotomograms and drawings of a normal TMJ obtained at slightly opened mouth and at maximum opening. The articular surfaces are coated by iodine contrast medium and outlined by air. In all drawings the disc is marked black.
- A. With slightly opened mouth, the upper compartment is seen in the fossa and along the articular tubercle. The lower compartment covers the condyle and has a recess anterior to the condyle. The disc stands out as a radiopaque area against the radiolucent air-filled joint compartments and is located with the posterior band (arrow) superior to the condyle.
- B. At maximum opening the condyle is located inferior and slightly anterior to the articular tubercle. The anterior parts of the compartments are narrow whereas the posterior parts are distended by the injected air. The posterior band of the disc (arrow) is seen posterosuperior to the condyle and there is articulation of the posterior surface of the condyle against the inferior surface of the disc.

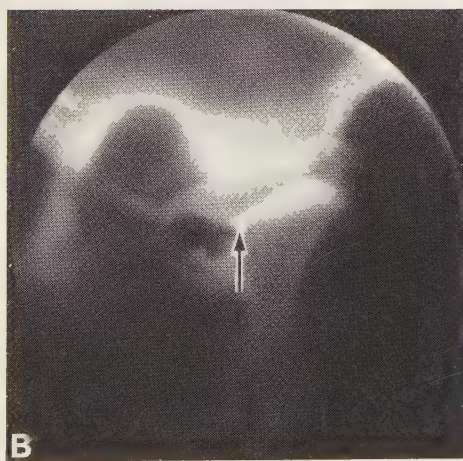
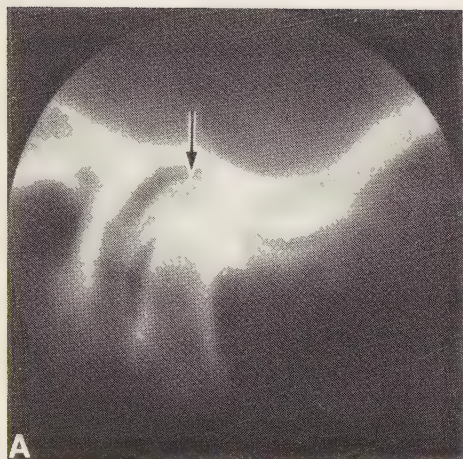


Fig 1

Fig. 2. Lateral double-contrast arthrotomograms and drawings of a right TMJ with anterior disc displacement with reduction.

- A. Arthrotomogram from the lateral third at intercuspal position. The upper compartment has a large triangular recess (arrows) inferior to the articular tubercle. The lower compartment exhibits an elongated recess anterior to the condyle (arrowhead). These abnormal configurations of the anterior parts of both joint compartments indicate an anterior displacement of the disc laterally. Leakage of contrast media into the extra-articular soft tissues is seen posteriorly and laterally along the neck of the condyle.
- B. Arthrotomogram from the same exposure as Fig. A representing a tomographic layer 10 mm more medially than that depicted in Fig. A. The anterior part of the upper compartment is narrow along the articular tubercle. The anterior part of the lower compartment is not as long as in Fig. A. The posterior band of the disc (arrow) is located superior to the condyle. The appearance of the compartments and the location of the disc closely correspond to a radiographically normal TMJ. The information from Figs 2 A and 2 B indicates an oblique position of the disc with the normal position medially and anterior displacement laterally.
- C. Arthrotomogram from the central part at maximum opening. During opening a distinct clicking was heard. Compared to Figs A and B additional air has been injected. The compartments are narrowed between the condyle and tubercle and are distended posteriorly. The disc is normally located with the posterior band (arrow) posterosuperior to the condyle and opposing the posterior surface of the condyle.
- D, E, F. Arthrotomograms from the same exposure obtained during the last part of the closing sequence. Fig. D represents the lateral part, Fig. E and F, 5 and 10 mm, respectively, more medially. The posterior band of the disc (arrows) is located posterosuperior to the condyle.

The posterior attachment of the disc to the capsule is folded (crossarrow Fig. E), most marked laterally. The anterior recess of the lower compartment exhibit varying appearances in the different mediolateral sections of the joint. In the lateral part (Fig. D) there is a leakage of contrast media along the neck of the condyle (arrowheads).

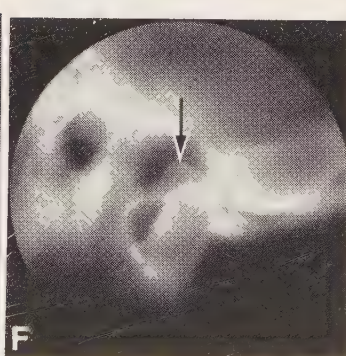
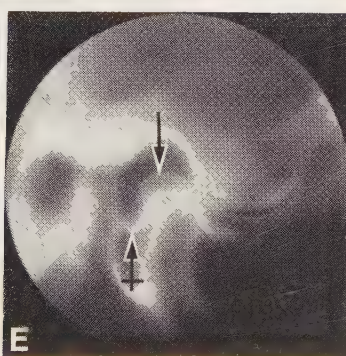
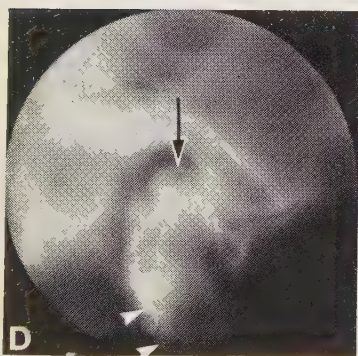
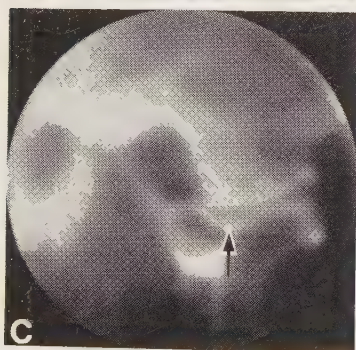
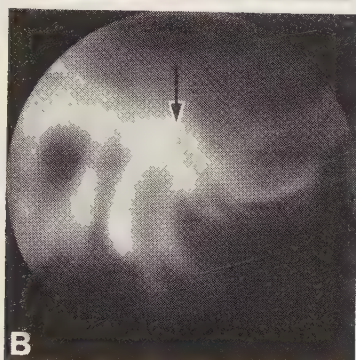
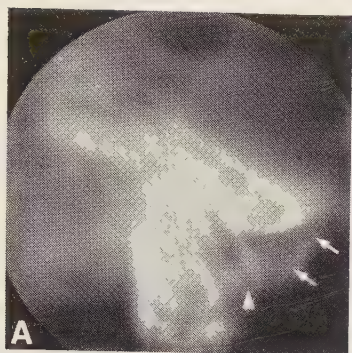


Fig 2

Fig. 3. Lateral double-contrast arthrotomograms and drawings of a right TMJ with anterior disc displacement without reduction obtained with slightly opened mouth and at maximum opening.

- A. With slightly opened mouth the biconcave disc is anteriorly displaced and the posterior band (arrow) is seen anterior to the condyle. The lower compartment exhibits an elongated recess anterior to the condyle.
- B. At maximum opening the disc is still anteriorly displaced and the posterior band (arrow) is seen anterior to the condyle and inferior to the tubercle. In this position there is a considerable elongation of the posterior attachment.

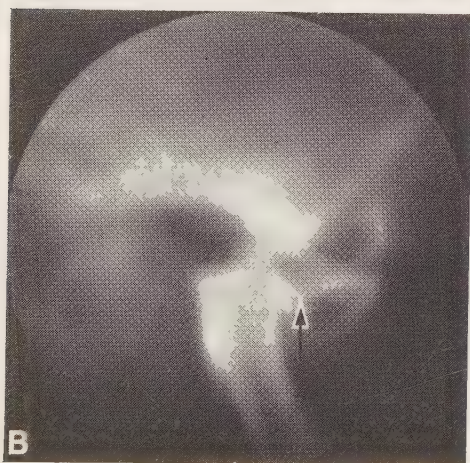
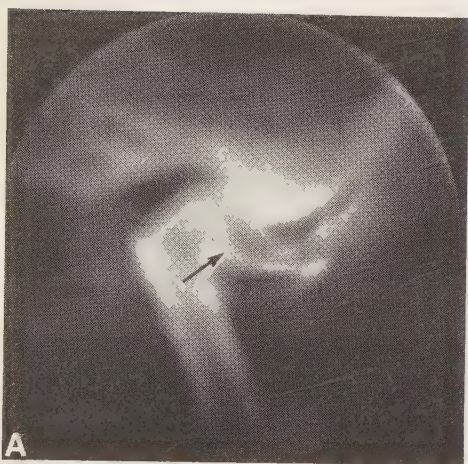


Fig 3

Fig. 4. Lateral double-contrast arthrotomogram and drawing of a left TMJ with anterior disc displacement without reduction at intercuspal position. The disc (arrow) is located anteriorly to the condyle which is positioned posteriorly in the fossa. In addition to the anterior displacement, the disc is deviated in form, being mainly biconvex. Leakage of contrast media is seen on the neck of the condyle (arrow-heads).

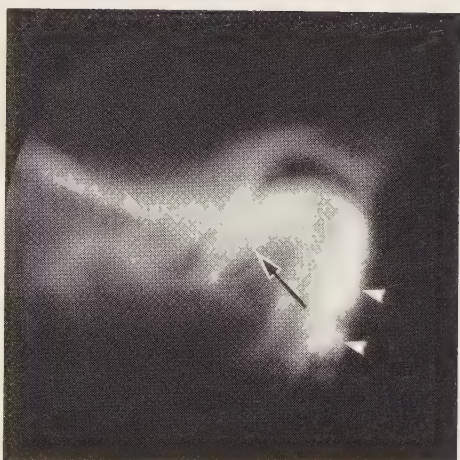


Fig 4

Fig. 5. Lateral double-contrast arthrotomograms and drawings of a left TMJ at maximum opening.

- A. Injection of iodine contrast medium into lower compartment resulted in simultaneous filling of lower and upper compartments indicating disc perforation. The disc is anteriorly displaced. Anterior to the condyle it is thick. The posterior part is obscured by the contrast medium.
- B. Most of the iodine contrast medium has been aspirated and replaced by air. This arthrotomograms represents the same tomographic level as Fig. A and was obtained after movements of the mandible. Compared to Fig. A the disc has a slightly different appearance anterior to the condyle. The posterior attachment of the disc to the capsule is thin (arrows). A septum (arrowhead) is seen in the posterior recess of the lower compartment.
- C. Double-contrast arthrotomogram from the same exposure as Fig. B representing a tomographic layer 2.5 mm more laterally. Discontinuity (arrows) in the posterior attachment of the disc to the capsule demonstrates the location and size of the perforation.

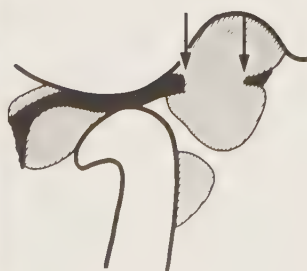
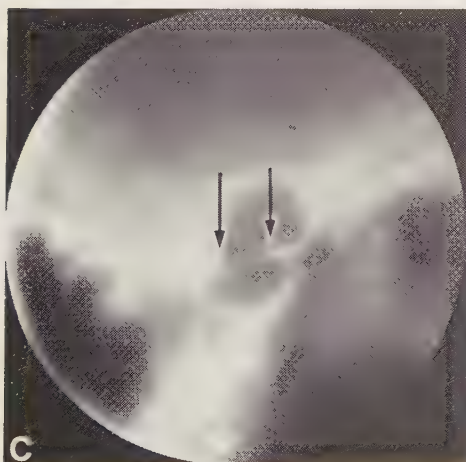
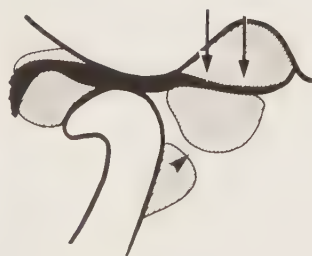
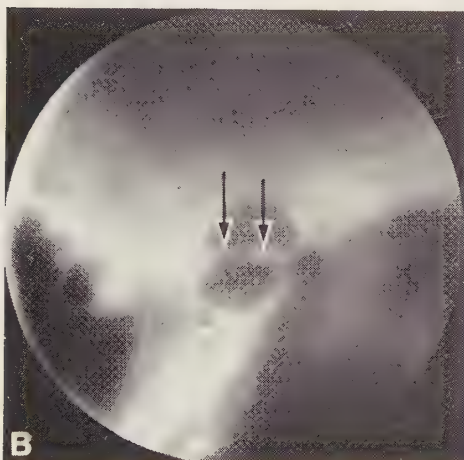
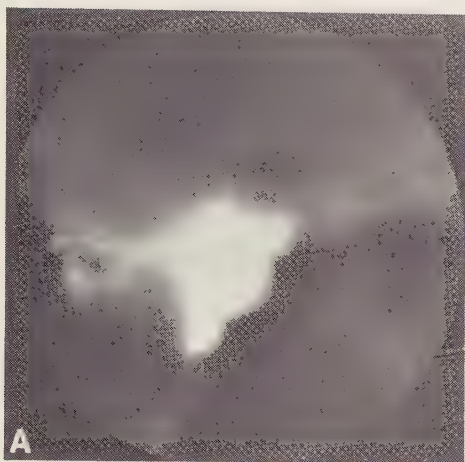


Fig 5

Paper VI

CLINICAL AND RADIOLOGICAL STUDY OF PATIENTS WITH
ANTERIOR DISC DISPLACEMENT OF THE TEMPOROMANDIBULAR
JOINT

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ABSTRACT

Patients displaying temporomandibular joint clicking or with a history of clicking followed by limitation of opening were subjected to clinical and radiological examinations including arthrography. Arthrotomographically the patients were found to have anterior displacement of the disc. In patients with clicking the disc was repositioned in association with clicking during opening. In patients with limitation of opening the disc was constantly displaced anterior to the condyle, blocking anterior condylar translation. The patients with limitation of opening had more pain, more signs of mandibular dysfunction, more hard tissue changes and more frequent perforation and deformation of the disc, compared to patients with clicking only. These findings may justify two different diagnoses, displacement with and without repositioning of the disc on opening. Displacement without repositioning seems to be the more advanced condition and may in some cases be a precursor of osteoarthritis.

SAMMANFATTNING

Patienter med käkledsknäppningar eller tidigare käkledsknäppningar, som följts av gapsvårigheter, undersöktes kliniskt och röntgendiagnostiskt. Röntgenundersökningen, som innefattade artrografi, visade att dessa patienter hade anterior displacering av käkledsdysken. Hos patienter med knäppningar korrigerades diskläget i samband med knäppning under gapning. Hos patienterna med gapsvårigheter var disken under hela gapningsrörelsen displacerad framför ledhuvudet och hindrade dess framåtgående. Patienter med gapsvårigheter hade jämfört med patienterna med knäppningar mer smärta, fler tecken på mandibulär dysfunktion, oftare strukturella hårdvävnadsförändringar, perforation och deformation

av disken. Anterior diskdisplacering förefaller representera två diagnoser, displacering med respektive utan korrigerig av diskens läge under gapning. Det senare tillståndet förefaller vara mera avancerat och kan i en del fall vara ett förstadium till artros.

INTRODUCTION

Disc displacement of the temporomandibular joint (TMJ) was surgically identified in 1887 (Annandale 1887). Later, it was described as a causative factor of TMJ pain and dysfunction (Pringle 1918-19, Ireland 1951, Silver, Simon & Sarastano 1956, Middleton 1970). However, it was not until the late 1970's that the role of specifically anterior disc displacement in TMJ pain and dysfunction was clarified by Wilkes (1978 a b), who combined observations from arthrography and surgery. He concluded that the mechanism responsible for the symptoms concerned the competency of the posterior articular disc attachment. His observations were confirmed by Farrar & McCarty Jr (1979), Katzberg, Dolwick, Helms, Hopens, Bales & Coggs (1980) and Bronstein, Tomasetti & Ryan (1981). Anterior disc displacement has even been put forward as a fundamental pathophysiological abnormality in the TMJ (Wilkes 1978 a b, Katzberg, Dolwick, Helms, Hopens, Bales & Coggs 1980).

According to the terminology recommended by the sixth annual Temporomandibular Joint Research Seminar (Chicago, July 1979, Katzberg, Dolwick, Helms, Hopens, Bales & Coggs 1980) anterior disc displacement may be subdivided into displacement with reduction (i.e. repositioning of the disc to normal superior position on opening usually associated with clicking) and displacement without reduction (i.e. without repositioning of the disc to normal superior position on opening usually associated with locking) (Fig. 1).

The radiological findings in patients with anterior disc displacement have been described (Wilkes 1978 a b, Farrar & McCarty Jr 1979, Blaschke, Solberg & Sanders 1980, Katzberg, Dolwick, Helms, Hopens, Bales & Coggs 1980, Bronstein, Tomasetti & Ryan 1981, Westesson 1982). However, the clinical symptoms and signs have been briefly described for patients showing displacement with and without reduction, respectively.

The aim of this prospective study was to delineate clinical as well as radiological observations of patients with anterior disc displacement and to compare findings in patients exhibiting displacement with reduction to those in patients showing displacement without reduction.

PATIENTS

During a period of two years, approximately 300 patients with TMJ disorders were referred to the Department of Oral Surgery, University Hospital of Lund. During the same period about 1900 patients, also with TMJ disorders, were referred to the Department of Stomatognathic Physiology, School of Dentistry, University of Lund. Two days a week one of the authors (LE) was able to examine about 300 of the 2200 patients. Fifty-nine of the 300 patients exhibited either clicking followed by transient or permanent limitation of opening. Four patients were excluded because of incomplete initial examination. Four other patients were excluded because of other diagnosis than anterior disc displacement. Our study is based on the remaining 51 patients. Table 1 presents age and sex distribution.

METHODS

Clinical history

Clinical history was obtained according to the criteria in Table 2. The patients were asked to classify the intensity of pain on a five step scale graded in: no pain, very slight pain, neither slight nor strong pain, strong pain, very strong pain. The use of analgetics against TMJ pain was recorded. A general medical history including afflictions in other joints was obtained.

Examination of temporomandibular joints, mandibular movements, masticatory muscles and occlusion.

Clinical examinations were performed by one of the authors (LE). Examinations of TMJs and mandibular movements were performed according to the criteria in Table 3. Clicking and crepitation were diagnosed by stethoscope. Hesitation during opening and closing movements was observed visually and by palpation of the TMJ. Maximal opening, protrusion and laterotrusion were measured according to the method described by Agerberg (1974). Deviation at the end of opening was estimated from an anterior view as a horizontal difference between black tape marks on the upper and lower left incisors.

The masticatory muscles were palpated in the way described by Krogh-Poulsen (1979) and tenderness recorded. The muscles palpated were those presented in a schedule by Hansson & Nilner (1975) supplemented with the sternocleidomastoideus, trapezius and suprahyoidal muscles.

The examination of occlusion was performed according to the criteria in Table 4. Vertical and horizontal overbites were measured according to the principles by Agerberg (1974). Tooth contact during movement from retracted to intercuspal position which resulted in a lateral mandibular deviation larger than 1 mm was

considered as interference. Mediotrusion (balancing) interference was present when tooth contact was missing on the laterotrusion (working) side due to tooth contact on the mediotrusion side. Interferences were recorded by the aid of sheets of wax (Kerr Casting Wax, sheets-soft, green, gauge No. 28).

Radiology

Radiologic examination included submento-vertical (axial) projection (Clark 1956), individualized lateral oblique transcranial projection at intercuspal position (centric occlusion), rest position and at maximal opening, serial lateral tomography at intercuspal position (Omnell & Petersson 1976), transmaxillary projection (McCabe, Keller & Moffett 1959, Moffett 1968, modified by Bean, Petersson & Svensson 1975) and arthrotomography (Westesson 1982).

In the tomograms the location of the condyle in the fossa at intercuspal position was referred to as anterior, central or posterior. A central position was recorded when the radiolucent space between the mineralized parts of the mandibular and temporal components was of even thickness. Anterior and posterior positions were recorded when the radiolucent space was smaller anteriorly and posteriorly, respectively. When different positions were seen in different parts of the joint the position present in most of the tomograms was registered. The condylar position at maximal opening was registered in relation to the articular eminence as posterior, inferior or anterior. Structural hard tissue changes were recorded according to the principles by Petersson & Nanthaviroj (1975).

The arthrograms were interpreted as described by Wilkes (1978 a b), Farrar & McCarty Jr (1979 b), Blaschke, Solberg & Sanders (1980). Katzberg, Dolwick, Helms, Hopens, Bales & Coggs (1980) and Westesson (1982).

Thus, the joints were classified as having normal disc position (Fig. 1 A), anterior disc displacement with reduction (Fig. 1 B) or anterior disc displacement without reduction (Fig. 1 C). In joints with anterior disc displacement the position of the disc was classified as either anterior or oblique. Oblique disc position implies normal superior position medially and anterior position laterally. The configuration of the disc in the arthrotomogram was classified as biconcave, biconcave with enlargement of posterior band, of even thickness or biconvex. Perforation of the disc was diagnosed by opacity of the upper compartment after injection of contrast medium into the lower compartment.

Statistical methods

The following statistical methods were used in order to compare patients displaying unilateral anterior disc displacement with reduction and those exhibiting unilateral anterior disc displacement without reduction:

- Chi-square tests for assessing if observed frequencies in 2 x 2 contingency tables (d.f. = 1) significantly differed from those expected.
- Fisher's exact test when expected frequencies were less than five.
- Wilcoxon's rank sum test for comparison of medians. The normal approximation was used to assess the level of significance.

Z-values were corrected for ties.

Levels of significance were based on two-tailed tests.

The following levels of significance were used:

0.05 < p not significant

0.01 < p $\leq$ 0.05*

0.001 < p $\leq$ 0.01**

p $\leq$ 0.001***

RESULTS

Twenty-two patients (12 females, 10 males) exhibited unilateral reciprocal clicking and were arthrotomographically found to have anterior disc displacement with reduction. Twenty-three patients (19 females, 4 males) exhibited unilateral transient or permanent limitation of opening with a history of clicking in 18 of the patients. Arthrotomographically these 23 patients were found to have anterior disc displacement without reduction. Ten of the 45 patients with unilateral complaints showed weak pain and/or clicking in the contralateral joint.

Six other patients (females) with bilateral complaints were clinically and arthrotomographically shown to have bilateral anterior disc displacement with reduction in three patients and without reduction in the other three.

The four remaining patients (females) exhibited unilateral pain in the TMJ region and had a history of clicking followed by limitation of opening. Conventional radiography showed limitation of anterior translation of the condyle. All these observations indicated anterior disc displacement without reduction. In three of these patients arthrotomography revealed biconcave discs in normal superior position not obstructing anterior translation of the condyle. The fourth patient exhibited a perforation in the lateral part of the disc which obstructed determination of the disc position laterally. Medially the disc was intact and located in a normal superior position. These four patients with a diagnosis other than anterior disc displacement were excluded from further analysis.

Clinical history findings

The clinical histories are summarized in Table 2. Patients exhibiting unilateral displacement with re-

duction had less pain ($\chi^2 = 5.75^*$) than those with unilateral displacement without reduction. The clinical history did not reveal other significant differences between the patients in the two groups. Some patients experienced the disappearance of clicking in association with the occurrence of locking as a partial relief of the affliction.

For both groups pain associated with mandibular movements was focused on the joint region. In ten of the patients with constant pain, this was located in the cheek and/or temple region. Transient locking was temporarily relieved by the patient by pressing laterally over the joint during opening, by performing a large deviation during opening or simply by knocking the mandible.

Two patients showed controlled diabetes, two suffered from psoriasis limited to a part of the scalp and a knee, respectively. Four patients reported clicking in other joints. One patient reported intermittent pain in the joints of one hand. One patient reported intermittent swelling of other joints (laboratory tests for rheumatic diseases were negative). One patient reported a tendency to sprain joints of the extremities. Six patients experienced intermittent pain from the neck, back or shoulder.

Dentists and/or physicians had previously treated 31 of the patients for their TMJ affliction with muscle relaxants, occlusal adjustments and/or splints without complete relief of the symptoms.

Clinical findings of temporomandibular joints, mandibular movements, masticatory muscles and occlusion.

The results are presented in Tables 3 and 4. Clicking occurred in both groups but was more frequent in patients showing displacement with reduction (at opening

$\chi^2 = 31.46^{***}$, at closing $\chi^2 = 41.17^{***}$). Crepitation was more frequent in patients with displacement without reduction ($\chi^2 = 6.43^*$). Lateral tenderness of the TMJ on palpation was more frequent in patients showing displacement without reduction ($\chi^2 = 6.51^*$). The patients displaying unilateral displacement without reduction compared to those showing unilateral displacement with reduction exhibited smaller maximal opening ($Z = 4.60^{***}$), more frequent deviation at the end of opening towards the affected side ($\chi^2 = 6.71^{**}$), pain in the affected joint during laterotrusion towards the affected side ($\chi^2 = 4.45^*$), towards the opposite side ($\chi^2 = 11.38^{***}$) and during protrusion ($\chi^2 = 12.47^{***}$). No other significant differences were found in TMJs and mandibular movement between the patients in the two groups.

The number of muscles which were tender on palpation was larger on the affected side than on the non-affected side in patients showing displacement without reduction ($\chi^2 = 7.04^{**}$). More molars were missing in patients exhibiting anterior disc displacement without reduction than in patients showing displacement with reduction ($\chi^2 = 7.03^{**}$).

Radiologic findings

The results are presented in Table 5. Patients showing displacement without reduction compared to patients displaying displacement with reduction, more frequently exhibited limitation of anterior condylar translation at maximal opening i.e. condyle posteriorly or inferiorly to the articular eminence ($\chi^2 = 27.25^{***}$), structural hard tissue changes ($\chi^2 = 12.47^{***}$), disc deformation i.e. of even thickness or biconvex ($\chi^2 = 29.47^{***}$) and perforation (Fisher's exact test: $p \approx 0.005^{**}$). An oblique disc position was more frequently observed in joints showing displacement with reduction ($\chi^2 = 11.03^{***}$).

DISCUSSION

Our study has shown that in this sample reciprocal clicking was a clinical sign of anterior disc displacement with reduction. Anterior disc displacement without reduction was clinically characterized by a history of clicking followed by limitation of opening. These patients demonstrated deviation towards the affected side at the end of opening, pain during laterotrusion towards the opposite side and during protrusion. Our findings confirm previous observations (Wilkes 1978 a b, Dolwick, Katzberg, Helms & Bales 1979, Katzberg, Dolwick, Helms, Hopens, Bales & Coggs 1980). Employing chi-square tests this study showed a definite difference of both clinical and radiological findings in patients displaying anterior disc displacement with reduction compared to those having displacement without reduction.

Posterior position of the condyle in the fossa at intercuspal position, as seen in transcranial oblique radiographs, has been proposed as a sign of anterior disc displacement (Farrar 1978). Using serial lateral tomography this sign was found in only 18 of 45 patients with anterior disc displacement. Limitation of anterior translation of the condyle at maximal opening was found in 21 of 23 joints exhibiting displacement without reduction and may be looked upon as a radiologic sign of this diagnosis.

Initially displacement without reduction may considerably restrict maximal opening. With a lapse of time, opening might slowly increase and eventually become normal. This might be achieved by elongation of the posterior disc attachment with further anterior displacement and advanced deformation of the disc. Therefore, as noticed by Katzberg, Dolwick, Helms, Hopens, Bales & Coggs (1980), increasing mouth opening in pa-

tients with anterior disc displacement without reduction should not be regarded as a normalization of joint status without reservation.

Joints showing displacement without reduction exhibited higher frequency of crepitation, structural hard tissue changes, disc deformation and perforation than those exhibiting displacement with reduction. This might indicate that displacement without reduction is a more advanced stage than displacement with reduction as was also suggested by Katzberg, Dolwick, Helms, Hopens, Bales & Coggs (1980). There might be a developing line of TMJ internal derangement from anterior disc displacement with reduction, through displacement without reduction to osteoarthritis which has been discussed in several papers (Wilkes 1978 a b, Farrar & McCarty Jr 1979, Bronstein, Tomasetti & Ryan 1981). On the other hand, all patients with anterior disc displacement with reduction do not advance into a displacement without reduction (Isberg-Holm & Westesson 1982 a b) and all patients with displacement without reduction do not develop osteoarthritis. Rasmussen (1981) described an orderly progress of symptoms in temporomandibular arthropathy. He found an initial stage of clicking and locking, an intermediate stage of pain and constriction and a terminal stage of crepitation and constriction followed by freedom of symptoms. The initial and intermediate stages are in agreement with the description of our patients. However, the radiographs published by Rasmussen (1980) display extensive structural hard tissue changes whereas radiographs of our patients reveal few such changes. This implies that Rasmussen's patients suffered from other derangements than our patients explained by different criteria for selection.

The clinical criteria used for selection of patients for this study have unveiled themselves as characteristic features of anterior disc displacement. However,

anterior disc displacement might be present concomitantly with other signs and symptoms. Therefore, the reliability of the criteria ought to be investigated in a randomly selected group of patients.

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Table 1. Age and sex distribution of the patients (n = 51).

Age	Male	Female	Total
10 - 19	3	5	8
20 - 29	6	12	18
30 - 39	1	11	12
40 - 49	2	2	4
50 - 59	1	4	5
60 - 69	0	3	3
70 - 79	1	0	1
Total	14	37	51

Table 2. Clinical history findings with respect to arthrographic diagnosis (n = 51).

	Patients with anterior disc displacement with reduction			Patients with anterior disc displacement without reduction		
	Unilateral (n = 22)	Bilateral (n = 3)	One side Both sides	Unilateral (n = 23)	Bilateral (n = 3)	One side Both sides
Median age, years	24.5	30		35	26	
Pain only in the TMJ region	12	2	0	18	0	1
Pain in the cheek and/or temple region	5	0	1	3	0	2
Pain only in association with mandibular movements	13	0	2	16	0	0
Constant pain	4	0	1	5	0	3
More intensive pain in the morning	6	0	0	4	0	0
More intensive pain in the evening	0	0	0	4	0	2
Intensity of pain more than two on a five step scale*	12	1	0	20	0	3
Sudden onset of clicking/hesitation	13	0	3	not disclosed	not disclosed	
Previous transient locking	11	2	1	14	1	1
Occurrence of transient locking has gradually increased	6	2	1	8	0	1
Previous trauma	3	0	0	3	0	0
Previous orthodontic treatment	1	0	0	2	0	0

* Five step scale graded in: no pain, very slight pain, neither slight nor strong pain, strong pain, very strong pain.

Table 3. Clinical findings of temporomandibular joints and mandibular movements with respect to arthrographic diagnosis (n = 51).

	Patients with anterior disc displacement with reduction			Patients with anterior disc displacement without reduction		
	Unilateral (n = 22)	One side	Both sides	Unilateral (n = 23)	One side	Both sides
Clicking/hesitation during opening movement	22	0	3	4	0	0
Clicking/hesitation during closing movement	22	0	2	1	0	0
Pain in association with clicking/hesitation during opening	3	1	1	1	0	0
Pain in association with clicking/hesitation during closing	0	0	0	0	0	0
Crepitation during opening or closing movement	1	0	0	8	1	1
Lateral tenderness of the TMJ on palpation	6	2	1	15	0	3
Posterior tenderness of the TMJ on palpation	6	1	1	6	0	1
Maximal mouth opening (mm): mean range	48.6 41-57	51.8 34-62	47.0 32-57	36.4 28-46	38.0 26-55	34.7 20-42
Pain at maximum opening	7	1	1	14	1	2
Deviation at the end of opening towards the affected side	5	-	-	14	-	-
Deviation at the end of opening towards the other side	4	-	-	0	-	-
Larger laterotrusion towards the affected side than towards the opposite side	9	-	-	13	-	-
Smaller laterotrusion towards the affected side than towards the opposite side	12	-	-	7	-	-
Equal laterotrusion towards both sides	1	-	-	3	-	-
Pain in the affected joint during laterotrusion towards the affected side	4	-	-	11	-	-
Pain in the opposite side	2	-	-	13	-	-
Protrusion larger than 5 mm	22	2	0	20	2	1
Pain in the affected joint during protrusion	3	0	0	15	2	1
Pain in the affected joint during retrusion	2	0	0	8	0	0

Table 4. Findings at examination of occlusion with respect to arthrographic diagnosis (n = 51).

	Patients with anterior disc displacement with reduction		Patients with anterior disc displacement without reduction	
	Unilateral (n = 22)	Bilateral (n = 3)	Unilateral (n = 23)	Bilateral (n = 3)
Patients without missing teeth (wisdom teeth excluded)	18	2	10	2
Patients with one to five missing molars	4	0	13	1
Patients with more than five missing molars	0	1	0	0
Vertical overbite > 3 mm	11	0	12	1
Horizontal overbite (overjet) > 3 mm	10	3	7	0
Interferences between retruded contact position and intercuspal position affected side	4	{ 1* }	5	{ 1* }
opposite side	6		3	
Mediotrusion (balancing) interferences affected side	4	{ 1* }	6	{ 1* }
opposite side	5		4	
Laterotrusion (working) interferences	0	0	0	0
Symmetric sliding between retruded contact and intercuspal position	18	0	17	2

* = both sides

Table 5. Radiologic findings of the temporomandibular joints with respect to arthrographic diagnosis (n = 51)

	Anterior disc displacement with reduction		Anterior disc displacement without reduction	
	Bilateral (n = 3)		Bilateral (n = 3)	
	Unilateral (n = 22)	One side Both sides	Unilateral (n = 23)	One side Both sides
PRE ARTHROGRAPHIC RADIOGRAPHY				
Position of the condyle in the fossa at intercuspal position	0	0	0	0
	11	2	16	3
	11	2	7	0
Relation between the condyle and articular eminence at maximal opening	0	0	13	1
	3	0	8	0
	19	0	2	2
Number of joints with structural hard tissue changes	3	0	15	1
ARTHROGRAPHY				
Configuration of the disc in the sagittal section	9	1	0	0
	12	1	3	0
	0	0	2	0
	0	0	14	3
	1	0	4	0
	12	0	2	0
Oblique disc position i.e. anterior displacement laterally and normal superior position medially	0	0	8	0
Disc perforation			2	0

LEGENDS

Figure 1. Schematic drawings of TMJs with different diagnoses. Position and outline of mineralized joint components, disc and joint compartments based on tracings from double-contrast arthrotomograms. Slightly opened mouth (left) and maximal opening (right). Dense part of disc marked with black and posterior band indicated by arrow.

- A. Normal superior disc position. Posterior band of disc superior to condyle at slightly opened mouth and posterosuperior to condyle at maximal opening.
- B. Anterior disc displacement with reduction (i.e. repositioning of disc to normal superior position on opening). Clicking observed during opening and closing. Posterior band of disc anterior to condyle at slightly opened mouth and posterosuperior to condyle at maximal opening.
- C. Anterior disc displacement without reduction (i.e. without repositioning of disc to normal superior position on opening). Limitation of opening observed. Posterior band of disc anterior to condyle both at slightly opened mouth and at maximal opening.



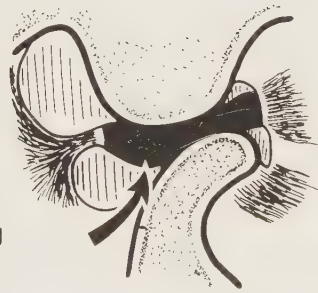
→
Normal



A



→
Clicking



B



→
Locking



C

Fig 1

Paper VII

INTERNAL DERANGEMENT RELATED TO OSTEOARTHROSIS
IN TEMPOROMANDIBULAR JOINT AUTOPSY SPECIMENS

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ABSTRACT.

In 127 temporomandibular joint autopsy specimens the position (superior 44%, oblique 22%, anterior 34%) and configuration of the disc (biconcave 56%, biconvex 10%, others 34%) were related to osteoarthritis. Biconvex discs were all positioned anteriorly and associated with osteoarthritis. Biconcave discs were mostly positioned superiorly and associated with normal surfaces.

INTRODUCTION.

In a general survey of orthopaedic disorders, internal derangement of joints was considered as one main predisposing factor for the development of osteoarthritis (Adams 1981). Speculations have been raised as to whether anterior disc displacement, considered as the principal internal derangement of the temporomandibular joint (TMJ) (Wilkes 1978 a) may progress to osteoarthritis (Wilkes a b; Farrar & McCarty Jr. 1979; Katzberg et al. 1980; Murphy 1981). In a recent study signs of osteoarthritis, such as crepitation, structural hard tissue changes as well as perforation of the disc, were found in patients showing displacement without reduction but hardly ever in patients showing displacement with reduction (Eriksson & Westesson 1982). Since displacement with reduction usually precedes displacement without reduction the observation by Eriksson & Westesson indicates that a progression may occur in some patients.

The sequelae of progression may be studied at post-mortem examination. Prevalence and distribution of osteoarthritis in the TMJ have been documented in several autopsy investigations (Blackwood 1963, Öberg et al. 1971; Lindvall et al. 1976; Bean et al. 1977).

However, recent concepts of position and configuration of the disc (Wilkes 1978 b; Katzberg et al. 1980; Westesson 1982) have not been related to osteoarthrosis.

Therefore, it was considered to be of interest to relate position as well as configuration of the disc to osteoarthrosis in TMJ autopsy specimens.

MATERIALS AND METHODS.

Material. - One hundred and twenty-seven right TMJ autopsy specimens were taken as blocks measuring approximately 10 cm x 8 cm x 6 cm through the middle cranial fossae from cadavers without infectious diseases. No other attempts were made to be selective. Age and sex distributions are seen in Table 1. Of the 127 joints, the number of remaining teeth was registered in 98 cases. Information of possible TMJ symptoms prior to death was not available.

Dissection. - After removal the fresh specimen was dissected. The temporal component was separated from the disc and the condyle by a circumferential incision in the capsule. The lower compartment was opened laterally, anteriorly and medially, while the disc remained attached to the condyle posteriorly. The disc was sagittally sectioned in a lateral, central and medial third without detachment from the condyle posteriorly. The joints were studied simultaneously by the authors and findings were recorded in a form prepared for computer processing.

The anteroposterior position of the disc relative to the condyle was classified according to criteria by Westesson & Rohlin (1982) as superior (Fig. 1 A) or

anterior (Fig. 1 B) for the lateral, central and medial thirds. For the entire disc the position was classified as superior, anterior or oblique. Oblique position implied anterior position laterally or laterally as well as centrally combined with superior position medially. Positions other than superior were considered as altered position.

Configuration of the disc was classified for the entire disc as well as for the lateral, central and medial thirds according to criteria by Westesson & Rohlin (1982) as biconcave (Fig. 1 A), of even thickness or biconvex (Fig. 1 B). Configurations other than biconcave were considered as altered configuration.

The articular surfaces of the lateral, central and medial thirds of the condyle, disc, fossa and tubercle were classified as normal or osteoarthrotic. The principles by Öberg et al. (1971) were adopted, thus "erosion and ruggedness" of the articular surfaces and perforation of the disc were classified as osteoarthrosis. Articular surfaces with remodelling or those showing no changes were classified as normal.

Statistical methods. The following statistical methods were used:

- Chi-square tests for assessing if observed frequencies mainly in 2 by 2 contingency tables (when otherwise not stated d.f. = 1) significantly differed from those expected.
- Fisher's exact test when expected frequencies were less than five.
- Wilcoxon's rank sum test for comparison of medians. The normal approximation was used to assess the level of significance. Z-values were corrected for ties. Levels of significance were based on two-tailed tests.

The following levels of significance were used:

0.05 < p not significant

0.01 < p $\leq$ 0.05*

0.001 < p $\leq$ 0.01**

p $\leq$ 0.001***

RESULTS.

Frequencies of position and configuration of the discs and osteoarthrosis are presented for the entire joints in Table 2 and for the lateral, central and medial thirds in Table 3. One joint with posterior disc position was excluded from statistical analysis concerning position and configuration of the disc. Three joints were excluded due to perforation of the entire disc and a fifth joint with perforation of the entire lateral third of the disc was excluded exclusively for the lateral third. Thus, the calculations concerning position and configuration of the discs for the lateral third are based on 122 joints and for the central and medial thirds on 123 joints. In one joint the posterior disc attachment occupied the entire fossa. This joint was excluded from calculations including the articular surface of the fossa.

Relation between diagnosis and age as well as number of teeth. - Individuals with osteoarthrosis (mean age 76) were slightly older ($Z = 2.3^*$) than those with normal articular surfaces (mean age 72). Position as well as configuration of the disc were not significantly related to age. When the joints were classified with respect to position of the disc, there were no significant differences in the median age of the individuals with osteoarthrosis compared to those with normal articular surfaces. When the joints were classified with respect to configuration of the disc, individuals with

osteoarthrosis (mean age 76) were slightly older than those with normal articular surfaces (mean age 71) in cases where the disc was of even thickness or of different configuration in different parts of the joint ($Z = 2.5^*$). When disc configuration was biconcave or biconvex there was no significant difference in the median age of individuals with osteoarthrosis and individuals with normal articular surfaces ($Z = 0.2$ N.S.). No significant difference was found between medians of number of remaining teeth in individuals with osteoarthrosis (median = 0, mean = 7) compared to individuals with normal articular surfaces (median = 0, mean = 6) ($Z = 0.5$ N.S.).

Disc position (Tables 2, 3). - Forty-four per cent of the discs were superiorly positioned (Fig. 1 A), 22% obliquely and 34% anteriorly (Fig. 1 B). Anterior position was more frequent in the lateral than in the central ($\chi^2 = 6.21^*$) and the medial thirds ($\chi^2 = 12.45^{***}$).

Disc configuration (Tables 2, 3). - Fifty-six per cent of the discs were biconcave (Fig. 1 A), 2% of even thickness and 10% biconvex (Fig. 1 B). Twenty per cent of the discs were of even thickness laterally and biconcave centrally and medially. Thirteen of 15 remaining discs were biconvex in one or two thirds. Deviation from the biconcave configuration was more frequent in the lateral than in the central ($\chi^2 = 18.57^{***}$) and medial thirds ($\chi^2 = 25.91^{***}$).

Association between position and configuration of the disc (Tables 2, 3). - There was a strong association between position and configuration of the disc ($\chi^2 = 57.47$, d.f. = 4^{***}). Superior position compared to anterior position was more frequently associated with biconcave configuration (Fisher's exact test $p < 0.001^{***}$). Oblique position compared to superior ($\chi^2 = 29.62^{***}$) as well as anterior position ($\chi^2 =$

8.55**) was associated with different configurations of the disc in different thirds of the joint. Superior ($\chi^2 = 29.62^{***}$) as well as anterior ($\chi^2 = 8.55$) position was associated with the same configuration in the entire joint. Discs of even thickness laterally were more frequently obliquely positioned than biconcave discs (Fisher's exact test $p < 0.01^{**}$). Association between superior position and biconcave configuration on one hand and anterior position and discs of even thickness or biconvex configuration on the other hand was also found for the lateral ($\chi^2 = 34.05^{***}$), central ($\chi^2 = 17.43^{***}$) and medial thirds ($\chi^2 = 18.74^{***}$).

Osteoarthrosis (Tables 1, 2, 3, 4). - Osteoarthrosis was found in 50 joints (age distribution in Table 1). Eleven TMJs exhibited osteoarthrosis simultaneously in the condyle, disc, fossa and tubercle. Osteoarthrosis was more frequent in the lateral third of the tubercle than in the central ($\chi^2 = 5.37^*$) and the medial thirds ($\chi^2 = 15.83^{***}$). In the disc osteoarthrosis was more frequently found in the lateral third than in the medial third ($\chi^2 = 10.94^{***}$).

Association between position of the disc and osteoarthrosis (Tables 2, 3). - Normal articular surfaces were associated with discs in superior position whereas osteoarthrosis was associated with oblique ($\chi^2 = 12.48^{***}$) and anterior ($\chi^2 = 18.07^{***}$) positions. In this respect there was no significant difference between oblique and anterior disc position ($\chi^2 = 0.12$ N.S.). In the separate thirds, the anterior position was associated with osteoarthrosis whereas the superior position was associated with normal articular surfaces, with the exception of the lateral third of the fossa.

Association between configuration of the disc and osteoarthrosis (Tables 2, 3). - Biconcave discs were associated with normal surfaces whereas discs of other

configurations were associated with osteoarthrosis ($\chi^2 = 36.91***$). This association was also obvious when comparing biconcave discs with discs of even thickness laterally ($\chi^2 = 13.61***$). In the separate thirds, biconcave discs were associated with normal articular surfaces whereas discs of even thickness or biconvex configuration were associated with osteoarthrosis.

Position and configuration of disc related to osteoarthrosis (Tables 2, 3). - Discs of even thickness or biconvex configuration in anterior position were associated with osteoarthrosis whereas biconcave discs in superior position were associated with normal articular surfaces (Fisher's exact test $p < 0.001***$). For discs in anterior position, biconcave configuration was generally associated with normal surfaces whereas other configurations were associated with osteoarthrosis (Fisher's exact test $p < 0.01**$). Osteoarthrosis was more frequent in joints with both altered position and altered configuration than in joints with merely altered position or merely altered configuration ($\chi^2 = 11.44 ***$).

DISCUSSION

Discs of even thickness or biconvex configuration in oblique or anterior position were frequently associated with osteoarthrosis whereas biconcave discs in superior position were mostly found in joints with normal articular surfaces. These findings support the assumptions made in recent clinical studies that internal derangement may progress to osteoarthrosis (Wilkes 1978 a, b; Farrar & McCarty Jr. 1979; Katzberg et al. 1980; Murphy 1981; Eriksson & Westesson 1982).

In patients, the position of the disc is diagnosed on

clinical as well as radiological observations of the function of the joint (Wilkes 1978, a, b; Farrar & McCarty Jr. 1979; Katzberg et al. 1980; Eriksson & Westesson 1982; Westesson 1982). In the present study the position was determined according to recently described criteria applied to autopsy specimens (Westesson & Rohlin 1982). These criteria were not related to function and allowed only small variations in the superior position. For these reasons false positive findings of anterior position were more likely than false negative findings.

The oblique disc position, described by Pringle (1918-19), has, later on, only been mentioned in few clinical reports (Katzberg et al. 1980; Eriksson & Westesson 1982; Westesson 1982). This is probably due to the fact that the lateral, central and medial parts of the TMJ are seldom examined separately. Clinically, oblique position was associated with displacement with reduction, while anterior position was associated with displacement without reduction (Eriksson & Westesson 1982; Westesson 1982). In the present study oblique position was found in one fifth of the joints. Oblique position was, as often as anterior position, associated with osteoarthritis. Further studies comparing oblique and anterior position may clarify whether oblique disc position justifies a separate diagnosis.

The most common deviation in configuration of the disc was even thickness laterally found in 20% of the joints. This deviation may correspond to lateral thinning (Hansson et al. 1977; Westesson & Rohlin 1982) which according to Hansson et al. (1977) "appears to be a result of the functional load as the disc in children does not show this lateral decrease".

Different definitions of osteoarthritis have been presented (Moffett et al. 1964; Sokoloff 1969; Öberg et

al. 1971; Hansson 1977; Carlsson & Öberg 1979). The principles by Öberg et al. (1971) are well established for macroscopic studies of the TMJ and were found to be suitable for the present investigation. These principles are basically in accordance with the definitions of osteoarthritis presented by Moffett et al. (1964), Sokoloff (1969) and Carlsson & Öberg (1979). Bean et al. (1977) proposed that the definition of osteoarthritis for the TMJ should be broadened to include the state of the subchondral change occurring simultaneously with intact articulating surfaces. Hansson (1977) included remodelling of the underlying hard tissue in his definition of osteoarthritis. Such changes were certainly missed in our study as their detection requires hard tissue examination such as radiography or histology.

It was beyond the scope of this investigation to report the relation between sex and osteoarthritis as well as the relation between dental status and the prevalence of osteoarthritis. This will be the subject for a future study in which tomographic appearance of the TMJ will be compared with the morphology of the dissected joint. However, in order to compare our material with material of previous autopsy studies some figures of frequency and distribution of osteoarthritis were calculated. In the present study osteoarthritis affected 39% of the joints compared to 40% found by Blackwood (1963) in a histological study of 400 TMJs removed from cadavers aged 40 years or older. Compared with joints from individuals 60 years of age or older in the autopsy study by Öberg et al. (1971) there was no significant difference in frequency of osteoarthritis in either the condyle, disc or temporal component. Osteoarthritis was most frequent in the lateral third of the joint in accordance with Öberg et al. (1971). This was also the most frequent location of altered position and/or configuration of the disc.

Osteoarthrosis is related to age (Blackwood 1963; Sokoloff 1969; Öberg et al. 1971; Kopp 1977; Gardner et al. 1980) and was confirmed by our study. Our conclusions concerning the association between disc status and osteoarthrosis can be justified since no significant association between position as well as configuration of the disc and age was found in our material.

Biconcave discs were most often found in superior position but one-fifth was found in anterior position. Conversely discs of other configurations were generally located in oblique or anterior position. Similar observations have been made in patients when employing arthrography (Westesson 1982).

Discs in oblique or anterior position as well as discs of even thickness laterally were associated with osteoarthrosis in 50% compared to 90% for biconvex discs. These data indicated the deformation of the disc to be in a more advanced stage than merely an altered position. One event in the early development of osteoarthrosis might be an altered position and this might be followed by an altered configuration. Progression to osteoarthrosis, a disease with multifactorial etiology, seemed however, not to be an inevitable result of altered position as only one-fourth of anteriorly positioned but biconcave discs were associated with osteoarthrosis. As osteoarthrosis represents "the final pathway of a variety of mechanisms" (Radin et al. 1980) internal derangement of the TMJ and osteoarthrosis should not be looked upon as a pathologic entity.

CONCLUSIONS.

Our results have shown association between oblique or anterior position as well as deformation of the disc

and osteoarthrosis. In the progression of internal derangement to osteoarthrosis not only the position, but also to a considerable extent, the configuration of the disc might be involved. Therefore, it may be valuable to diagnose both position and configuration of the disc in separate parts of the joint in order to provide optimal information for treatment planning and prognosis. Clinically, double-contrast arthrotomography (Westesson 1982) provides such information, and future interaction between diagnosis and progress in therapy might show its value.

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TABLE 1. AGE AND SEX DISTRIBUTION (n = 127). NUMBERS IN PARENTHESES INDICATE THE NUMBER OF JOINTS WITH OSTEOARTHRISIS

		30-39	40-49	50-59	60-69	70-79	80-89	90-99	Total	Mean age	
										All joints	Joints with osteoarthritis
Female	1	2	1(1)	14(5)	19(10)	14(8)	7(4)	58(28)	75	77	
Male	0	0	8(1)	14(3)	34(14)	8(1)	5(3)	69(22)	72	76	
Total	1	2	9(2)	28(8)	53(24)	22(9)	12(7)	127(50)	73	76	

TABLE 2. FREQUENCY OF POSITION AND CONFIGURATION OF DISC
(n = 122*). NUMBERS IN PARENTHESES INDICATE THE
NUMBER OF JOINTS WITH OSTEOARTHROSIS (n = 45*)

Configuration	Position			Total
	superior	oblique	anterior	
Biconcave	46 (4)	7 (1)	15 (4)	68 (9)
Biconcave with lateral third of even thickness	5 (1)	10 (6)	9 (5)	24 (12)
Of even thickness	2 (2)	1 (1)	0	3 (3)
Biconvex	0	0	12 (11)	12 (11)
Different configuration in different thirds of joint	1 (1)	9 (6)	5 (3)	15 (10)
Total	54 (8)	27 (14)	41 (23)	122 (45)

* Five joints with disc perforation excluded; disc position not disclosed (4) and posterior position (1).

TABLE 4. FREQUENCY AND DISTRIBUTION OF OSTEOARTHROSIS IN
LATERAL, CENTRAL AND MEDIAL THIRDS OF CONDYLE,
DISC, FOSSA AND TUBERCLE (n = 127)

Articular surface	Lateral	Central	Medial
Condyle	20	20	13
Disc	29	18	10
Fossa*	14	15	12
Tubercle	34	19	10

* n = 126 One fossa excluded as it was occupied by the posterior disc attachment.

LEGENDS

Fig. 1. Sagittal sections in central part of temporomandibular joint autopsy specimens. Anteriorly to the right and posteriorly to the left.

- A. Biconcave disc in superior position. Arrow indicates posterior band superior to condyle.
- B. Biconvex disc in anterior position. Arrow indicates border between dense part of disc and elongated posterior attachment.

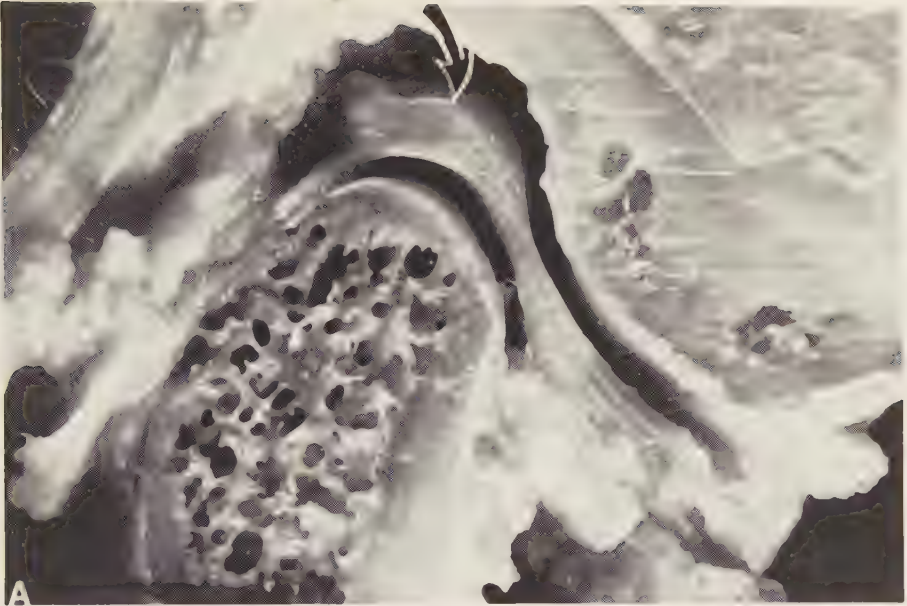


Fig 1



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